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**THE ROLE OF NATIONAL GEOLOGICAL SURVEYS
IN MINERAL RESOURCES DEVELOPMENT**

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**THE ROLE OF NATIONAL GEOLOGICAL SURVEYS
IN MINERAL RESOURCES DEVELOPMENT***

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Introduction

1. Mineral deposits and oil fields are a consequence of their geological environment and their discovery is dependent upon the basic knowledge of a nation's geology. Likewise, damsites for hydroelectric power, quarries and gravel banks for road construction and underground water for farm and city use are resources whose development rests heavily on geological considerations. Thus a nation who would know its natural resources must first know its geology. During the past century, most of the countries in the world have found it advantageous to maintain a national geological survey whose responsibility is to gather, to sort, and to make available the cumulative knowledge of the nation's geology.

2. Other papers will discuss the development of mineral resources. It is pertinent here only to remind the reader that a potential stone quarry, mineral deposit, or oil field becomes a resource only in the measure that it is used in the development of a nation's economy. Undeveloped mineral resources, unlike money in the bank, earn no interest.

3. The broad considerations presented in this paper are based upon observations during the past two decades during which the U. S. Geological Survey has actively been engaged in giving technical assistance in geology to other countries under the auspices and with the financial support of the Agency for International Development and its preceding organizations of the Government of the United States. The paper is addressed to those legislative and administrative governmental officers who plan and who authorize governmental expenditures in natural resource development rather than to the professional geologist to whom most of this material will already be familiar.

The task

4. The task of a national geological survey, inherent in its title, is to study, in the broadest possible sense, the geology of the nation. Geology must be interpreted broadly to include not only the fundamental mapping of rock units by the field geologist but also to employ the supporting services of paleontology, petrology, geophysics, geochemistry, and many other specialized techniques that are discussed in other papers at this meeting.

5. The task begins with the preparation of adequate base maps, which, in some countries are prepared by the national geological survey and in others by some national mapping organization without geological responsibilities. Either system can be effective if there is close correlation in planning to assure the readiness

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of proper base maps at the time geological mapping is to begin.

6. The mapping scale chosen is generally a compromise arrived at after consideration of the total area to be mapped, the complexity of the geology and the availability of competent geologists to do the field work. There is always an understandable desire for as much geological detail as possible requiring larger map scales which must be balanced against the limiting factors of total area, scheduled time and available personnel.

7. Commonly, a compromise is reached in which the areas either known to be mineralized or holding the greatest promise of mineralization are mapped on a larger scale than that used for the other parts of the nation.

8. With the development of photogeology in recent years, the question frequently arises as to the relative merits of photogeology and conventional field methods. There is no doubt that in suitable terrane photogeologic methods permit a much faster coverage of large areas than can be done by other means. It must be borne in mind that photointerpretation is dependent upon considerable knowledge of the composition of the rocks, their succession and their topographic expression. Again, a compromise is generally advisable in which photo methods are used by a field geologist to extend and amplify what he can see from the ground. Photogeology can best be regarded as just another tool of the field man, rather than as a substitute for him.

9. Within recent years airborne geophysical surveys have been widely used. It must be kept in mind that such surveys involve no magic perception but only provide a means for measuring and recording certain physical differences in the rocks over which the plane flies, such as magnetic permeability, nuclear radiation or electromagnetic induction.

10. Differences in the magnetic field essentially are due to differences in the magnetite content of the rocks below. A large deposit, even deeply buried, of magnetic iron ore is readily recorded and differences between igneous rocks containing even small percentages of magnetite and some sedimentary rocks that do not contain magnetite are also recorded. Other differentiations such as the depth of sedimentary cover, as is used in petroleum exploration, are more subtle and difficult to interpret.

11. Radioactivity measurements are made with a recording scintillation counter carried in the plane. Under favorable conditions of little or no cover, deposits of radioactive minerals of uranium and thorium can be detected from the air. Airborne measurements can detect differences of radioactivity as small as 6 parts per million, which gives us a useful geological tool for differentiating rocks of unequal amounts of contained radioactive minerals.

12. Certain metallic minerals occurring at shallow depths can be detected by plane borne electromagnetic devices. Great care and considerable experience are required in the interpretation of the record. This method has been very successful in the Canadian Shield.

13. A combined magnetic and radioactivity airborne survey costs approximately seven U.S. dollars per linear kilometer. The maximum spacing of flight lines, for mineral investigation, is approximately one kilometer. Thus, the basic cost per thousand square kilometers is of the order of \$6,000.

14. Electromagnetic induction methods require closer flight lines with a maximum interval of approximately one half kilometer. The basic cost of a combined electromagnetic induction, magnetic and radioactivity airborne survey is of the order of

\$15,000 to \$20,000 per thousand square kilometers.

15. These approximate costs apply to a survey of the general magnitude of 10,000 linear kilometers. To this must be added the costs of bringing the plane into the area and returning it to its home base. In areas of uncertain flying weather, a "stand by" charge is also made for the time the plane is grounded by bad weather. The above figures are intended only to be illustrative of the general magnitude of costs for airborne geophysical surveys in recent years.

16. Airborne geophysical surveying is expensive and, unless its planning is carefully based on considerable knowledge of the geology of the terrain to be flown, the money spent on the survey may be wasted. In planning such airborne geophysical surveys due consideration must be given both to the likelihood of new direct discoveries, such as a magnetite, uranium, or sulfide ore body, and to the probability of obtaining geophysical profiles that, while not leading to direct discovery of ore bodies, do give useful information about formational contacts and structural attitudes. The geological administrator who is considering undertaking an airborne geophysical survey must, in the light of his knowledge of the geology of the area to be investigated, weigh the probability of obtaining useful information against the cost of other possible field methods.

17. The backbone of any geological survey is its field geologists. The muscle and flesh are the specialists - paleontologists, petrographers and others whose specialized knowledge is necessary for the interpretation of the geological picture. Most field geologists have specialties. Thus a stratigrapher-paleontologist would study an area of sedimentary rocks while a petrographer would map a region of dominantly igneous rocks. Only the larger geological surveys of the industrialized nations can, expectably, have a full complement of all the specialists who can contribute to the understanding of all of the branches of geology. The smaller nations, necessarily dependent upon a smaller geological staff, must use great care in selecting and in training their geologists in the fields of specialization that locally are most important.

18. In general, a geologist's usefulness bears a direct relationship to his knowledge of the geology in the area where he works. As such knowledge is cumulative, each season in the field increases his value to the nation. This growth in usefulness is a factor worthy of serious consideration by a nation's geological administrators. Not only should experienced men be encouraged to continue their work, but provision must be made for a steady supply of new and younger men, chosen for their basic education, to grow into the experienced geologists of the future.

19. The problems of geological education are discussed in other papers at this meeting. It is pertinent here, however, to point out that many of the smaller nations, for some years in the future, will be dependent upon foreign education for their geologists. Most of the industrial nations are prepared to share their educational facilities and to undertake the training of the young geologists of the emerging countries. In the last two decades, the United States Geological Survey has welcomed 569 young geologists from 66 different countries who have worked in our field parties and our laboratories and who have attended our universities. The problems of education and training deserve serious and continued consideration by the geological administrators of the younger nations.

20. Geological information should be made available to possible users at the earliest possible time. The established geological surveys publish maps and reports in various formats. Provision should be made for strict internal scientific criticism of these maps and reports prior to publication so that the information they contain is both accurate and well expressed. Good administrative judgment is always needed to weigh timeliness against perfection, but timeliness

should never be an excuse for poor workmanship, either in the field or in publication format. It is interesting to note that, in recent years, members of some of the younger geological surveys have shown an increasing interest in the techniques of copy preparation, map drafting for color separation and other details of the publication process.

21. Briefly, it is the task of the geological administrator to carefully define the goals of his survey, to establish the work priorities, to choose scales and mapping methods, to encourage his experienced scientific personnel and to intelligently recruit the personnel of the future and, finally, to present the results as promptly and as lucidly as possible.

Some difficulties in recent years

22. Within recent years the geological surveys of some countries have suffered serious loss of scientific personnel either as a consequence of currency inflation or through repatriation.

23. The geological surveys of some of the semi-industrialized nations have suffered from lack of adequate financial support and continuing loss of geologists and other scientists to higher-salaried industrial positions. These losses have been particularly acute in countries that have experienced rapid currency inflation that has not been compensated by adequate and timely salary increases or cost of living allowances. Generally, the basic need for resources development has been disregarded in the press of political and social problems that arose from the inflation. The greatest tragedy in such cases is the interruption of recruitment of the young geologists upon whose work future development should rest.

24. Most of the countries that have attained independence during the past two decades inherited some form of a national geological survey, but, in some countries, the loss of inherited scientific personnel has outstripped their replacement by adequately trained nationals. When one considers that four years of university work is a bare minimum training for a young geologist, it may be several years before some countries can overcome their losses in trained personnel.

Foreign geological assistance

25. In recent years several of the industrialized countries, some of the specialized agencies of the United Nations, and the Colombo Plan have given technical assistance in geology. This assistance has taken several forms ranging from short time consultants in specialized fields to broad technical aid extending over a decade. Recently, the Special Fund of the United Nations has financed geological and geophysical surveys and drilling campaigns in a number of countries.

26. Technical assistance in geology by the United States Government began in 1940 and has continued to the present time during which 291 geologists, hydrologists and other earth scientists of the U. S. Geological Survey have executed 423 different assignments in cooperation with geologists in 57 different countries under the auspices and with the financial support of the Agency for International Development and its preceding organizations of the Government of the United States. In this time over 500 young geologists from more than 60 countries have received training in the U. S. Geological Survey as a part of the technical assistance program.

27. Our own experience in working abroad has been a happy one, unmarred by any serious incidents of misunderstanding with our fellow geologists. The projects have been truly cooperative for our geologists have worked with the geologists of the host country in the field and their reports have been published under the joint authorship of the two nationals. As a result of the last 20 years of our

foreign geological cooperation, more than five hundred geological reports and other scientific papers have been published.

28. In many countries there is still need for foreign technical assistance in geology and this need will not be fully satisfied within the next decade. It is well, however, to keep firmly in mind that the ultimate objective of such assistance is to see the host country attain scientific self-sufficiency. Thus, the technical aid programs of both the industrialized nations and of the international bodies like the United Nations and the Colombo Plan must be considered as temporary measures designed to aid the emerging nations in attaining their own scientific stature and technical self reliance.

Continuity of effort

29. Past experience has shown that the geological inventory is never finished. Geological Surveys should be established as permanent institutions, adequately staffed, to meet the continuing geological needs of the country. Many past failures have resulted from a narrower objective. Most of the industrialized nations have long-established geological surveys and their present task is to improve and refine the great store of geological information that they have gathered through the years of their existence. This involves remapping on larger scales as the need for more detailed information arises. It involves the application of new techniques and the reinterpretation of old data from newer scientific viewpoints. It will involve the training of new generations of earth scientists in the scientific arts that the future will surely bring. All these are thoughts that the skillful geological administrator and the enlightened legislator must ever keep in mind.



**КОНФЕРЕНЦИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ
ПО ВОПРОСУ О ПРИМЕНЕНИИ НАУЧНЫХ И ТЕХНИЧЕСКИХ ЗНАНИЙ
ДЛЯ УДОВЛЕТВОРЕНИЯ ПОТРЕБНОСТЕЙ МЕНЕЕ РАЗВИТЫХ РАЙОНОВ**

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СССР

**ЭФФЕКТИВНАЯ МЕТОДИКА ПОИСКОВ ТВЕРДЫХ
ПОЛЕЗНЫХ ИСКОПАЕМЫХ В МЕНЕЕ ИЗУЧЕННЫХ РАЙОНАХ**

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Документы, составленные для Конференции Организации Объединенных Наций по вопросу о применении научных и технических знаний для удовлетворения потребностей менее развитых районов, служат в качестве рабочих документов для этой Конференции. Они опубликованы в том виде, в каком были представлены их составителями, и их содержимое и выраженные в них мнения принадлежат их составителям (см. примечания на оборотной стороне).

ПРИМЕЧАНИЯ

1. Документы, включенные в число материалов, принятых для обсуждения на общих сессиях, будут в распоряжении делегатов Конференции на следующих официальных языках Организации Объединенных Наций: русском, английском, испанском и французском.

2. Документы, включенные в число материалов, принятых для обсуждения на специализированных сессиях, будут в распоряжении делегатов Конференции только на одном из этих официальных языков.

3. Резюме всех документов в том виде, в каком они были представлены их составителями, будут в распоряжении делегатов Конференции на следующих официальных языках Организации Объединенных Наций: русском, английском, испанском и французском.

4. До открытия Конференции документы и резюме не будут выпущены для общего распространения. Они будут опубликованы заблаговременно только в ограниченном числе экземпляров и исключительно для правительственных делегаций и других правомочных участников. Последующие опубликование и рассылка трудов Конференции будут обеспечены в соответствии с практикой Организации Объединенных Наций, как это установлено ее Издательским комитетом.

**"ЭФФЕКТИВНАЯ МЕТОДИКА
ПОИСКОВ ТВЕРДЫХ ПОЛЕЗНЫХ ИСКОПАЕМЫХ
В МЕНЕЕ ИЗУЧЕННЫХ РАЙОНАХ"**

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Советский Союз выполняет крупные поисковые работы в Сибири, Средней Азии, Казахстане и других менее изученных районах. Поиски ведутся практически на все известные виды полезных ископаемых, относящихся к различным генетическим типам. Работами охватываются громадные территории, расположенные в разнообразных природных условиях: в лесных и пустынных областях, в степях и горах. Успешный опыт советских геологов может быть применен в других странах.

Геологические работы целесообразно увязывать с единым для данной страны или для крупного региона, многолетним планом освоения минеральных богатств, с учетом требований развития и размещения национальной промышленности, сельского хозяйства, дорожного строительства и нужд экспорта. Наличие такого плана, позволяет намечать очередность работ, дифференцировать объекты капиталовложений, а также избегать дублирования геологоразведочных операций.

Поисковые работы отдельных геологических экспедиций и партий должны выполняться по определенным взаимно согласованным проектам. Эти проекты основываются на изучении данных о месторождениях, геологических предпосылках и поисковых признаках, позволяющих выделить наиболее перспективные объекты и районы работ, а также выбрать рациональную методику поисков.

Для наиболее уверенного оконтуривания перспективных площадей, составляются геолого-поисковые карты. Основой их являются геологические карты масштабов порядка 1:1.000.000 - 1:200.000. На эти карты наносятся все важные для оценки рудности данные, собранные в процессе предшествующих геологических исследований: месторождения полезных ископаемых /с указанием их генетического типа и размеров/, рудопроявления, радиоактивные, магнитометрические и другие геофизические поля и аномалии различной интенсивности, геохимические аномалии, минералогические, структурные, геоморфологические и прочие прямые и косвенные признаки полезных ископаемых. Во избежание перегрузки карт, производится геолого-генетическая группировка поисковых признаков или применяется систе-

ма накладок. Геолого-поисковые карты систематически пополняются новыми данными в ходе последующих поисковых работ.

Анализ геолого-поисковых карт, с учетом закономерностей образования и приуроченности месторождения к различным геологическим комплексам, позволяет выделить перспективные для поисков геологические структуры и площади.

Методика поисков рассчитана на одновременное обнаружение возможно более широкого круга полезных ископаемых с помощью комплекса ведущих и вспомогательных методов. Стоимость и скорость исследований на каждом этапе, в основном, определяются ведущими методами, которые применяются в определенной последовательности. Сначала работы производятся скоростными методами, позволяющими быстро оценить большие территории и выявить наиболее легко открываемые крупные месторождения, рудные поля и районы. После этого, переходят к использованию трудоемких методов. Последние дают возможность не только углубить представление о выявленных скоростными методами месторождениях, но и обнаружить новые, с менее отчетливо проявляющимися признаками. Этот порядок работ дает хорошие результаты, но не всегда обязателен.

Поиски на всех этапах тесно увязываются с геологической съемкой.

Наиболее скоростными и дешевыми являются аэрометоды. Из них, в качестве ведущих, применяются методы дешифрирования аэрофотоснимков и аэрогеофизические.

Для успешного геологического и поискового дешифрирования аэрофотоснимков желательно, чтобы территории будущих геологических работ фотографировались с воздуха заблаговременно по методике, учитывающей геологические задачи. Данные аэрофотосъемки позволяют быстро уточнить важные для поисков детали геологических карт и представляют надежный материал для выявления полезных ископаемых.

Так, использование стратиграфических и литологических критериев, позволяет обнаруживать признаки месторождений углей и сланцев, строительных материалов, фосфоритов, бокситов, железа и других полезных ископаемых, приуроченных к породам определенного состава и возраста. Структурным критерием пользуются при поисках экзогенных месторождений, контролируемых складчатыми структурами и многих эндогенных, например, приуроченных к разломам. Инструментальное дешифрирование аэрофотоснимков, дает возможность с успехом пользоваться геоморфологическим критерием, позволяя обнаруживать, например, алмазоносные кимберлитовые трубки, благодаря своеобразной скульптуре их эрозионной поверхности, выступающие в рельефе пласты железистых кварцитов, зоны окварцованных пород, дайки порфиритов, кварцевые и пегматитовые жилы и пр. Широко используется геоморфологическое дешифрирование для поисков металлоносных россыпей и рыхлых строительных материалов.

Благодаря цветовым отличиям от вмещающих пород, по аэрофотоснимкам можно обнаружить зоны скэрнов, окварцевания, хлоритизации, серитизации, оталькования, часто являющиеся прямыми или косвенными признаками различных месторождений. Применение крупномасштабной цветной и цветной спектрозональной аэрофотосъемки, увеличивает возможности обнаружения измененных пород, окисленных выходов, а иногда и непосредственно первичных руд месторождений.

Аэрофотоснимки всесторонне используются также при всех аэрогеофизических и наземных видах поисков.

В комплексе поисковых работ на недостаточно изученных территориях большую роль играют аэрогеофизические поиски, главным образом, с помощью автоматической станции, соединившей в себе аэро-радиометр, аэромагнитометр и радиоальтиметр. Аэро-радиометр этой станции снабжен каналом разделения, позволяющим с воздуха различить существенно урановый наземный источник гамма-излучения от ториевого. На борту самолета устанавливается также широкоугольный аэрофотоаппарат для фотографирования участков геофизических аномалий.

Работы с помощью комплексной станции производятся в масштабе 1:25.000 - 1:50.000. Высота полета самолета на равнинах - 25 м - 50 м. В горных районах применяется специальное построение маршрутной сети и геофизическая аппаратура устанавливается преимущественно на вертолетах. Аэро-радиометрические и аэромагнитные карты при дешифрировании сопоставляются с геологическими картами и с аэрофотоснимками. Выявленные геофизические аномалии, проверяются на земле специальными отрядами, снабженными легкими буровыми станциями, походными лабораториями и другим необходимым оборудованием.

Аэро-радиометром обнаруживается не только собственно урановые и ториевые руды, но и месторождения, в которых радиоактивные элементы являются сопутствующими, например, месторождения тантала, ниобия и др. редких и рассеянных элементов, молибдена, иногда олова, свинца, железа, висмута, золота, титана, селена, бокситов, нефелиновых сиенитов, углей и пр. Необходимым условием для эффективного применения аэро-радиометрии, является выход на поверхность руд или их радиоактивных ореолов рассеяния. Поэтому, крупные площади, закрытые чехлом рыхлых отложений мощностью более нескольких метров, аэро-радиометром не обследуются. Аэромагнитометрия играет наиболее важную роль при поисках магнитных железных руд, а также руд титана, хрома, иногда бокситов /платформенного типа/, медно-колчеданных и медно-никелевых руд. Хорошие результаты дает совместное дешифрирование аэро-радиометрических и аэромагнитных данных. Этот метод, например, сыграл большую роль в быстром расширении алмазonoсных площадей, поскольку кимберлитовые трубки отмечались четкими магнитными аномалиями и пониженными значениями радиоактивности. Аналогичные свойства имеют и массивы дунитов и др. ультраосновных и основных пород, с которыми обычно связаны месторождения платины, хрома и пр.

Россыпные месторождения титана, благодаря присутствию в них радиоактивных монацита и циркона, а также магнетита, были обнаружены по совпадающим аэромагнитным и аэро-радиометрическим аномалиям.

Аэромагнитометрия широко применяется также в качестве самостоятельного вида поисков.

Таким образом, применение только одних аэрометодов, позволяет быстро ревизовать перспективные районы на весьма широком круге полезных ископаемых, важных для народного хозяйства любой страны. В равнинных районах аэропоиски успешно дополняются автомобильными геофизическими площадными и маршрутными исследованиями.

Однако, после аэрогеологических и аэро- и автогеофизических

работ территории, естественно, все же не могут считаться надежно опомскованными.

Сплошная залесенность, например, мешает дешифрированию аэро-фотоснимков, высокогорный рельеф — применению скоростных геофизических методов, площадное развитие выщелочных почв и кор выветривания и чехол рыхлых отложений — аэро- и авто-радиометрическим работам. Некоторые полезные ископаемые, например, полиметаллы, вольфрам, олово, вообще плохо регистрируются при аэропоисках. Поэтому, вслед за скоростными аэрометодами, в перспективных районах, применяются более трудоемкие шлиховые и геохимические поиски по методике, разработанной советскими специалистами.

Советская методика основывается на знании закономерностей формирования солевых и механических ореолов рассеяния месторождений полезных ископаемых в различных природных условиях с учетом геохимии ландшафтов, характера обводненности, рельефа и кор выветривания, состава и мощности рыхлых отложений, типа почв и растительности. Применение ее помогло Советскому Союзу решить проблему обеспечения минеральным сырьем многих районов Сибири, Казахстана, Средней Азии и Урала.

Шлиховые методы оказались эффективными при поисках коренных и рассыпных месторождений золота, олова, платины, алмазов, вольфрама, ртути, редких элементов титана и других минералов. Геохимические методы позволили выявить крупные месторождения меди, свинца, цинка, молибдена и других полезных ископаемых, причем некоторые месторождения найдены на площадях, ранее детально опомскованных другими методами.

Возможность быстрой оценки обширных площадей по сравнительно небольшому числу проб, достигается металлотрическим и шлиховым опробованием данных осадков речной сети. При поисках в масштабе 1:200.000 на 1 км² при этом отбирается, обычно, не более 4-5 проб шлихи, после различных видов сепарации, изучаются минералогически с подсчетом количества встречающихся рудных минералов или минералов-спутников, иногда играющих важную роль при поисках. Например, самые первые коренные месторождения алмазов в Сибири были найдены путем изучения распространения в шлихах пиропов и других легче обнаруживаемых, чем сами алмазы, минералов-спутников.

Металлотрические пробы иловато-глинистых речных осадков, подвергаются полуколичественному спектральному анализу с определением обычно 30 химических элементов /Li, Be, B, F, P, Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Ge, As, Sr, Zr, Nb/

или Ga /Mo, Ag, Sr, Sb, Ba, Ce, V, W, Hg, Pb, Bi, U/ а также измерения на радиометрах. В районах, где комплекс ожидаемых полезных ископаемых уже определен, перечень анализируемых элементов сокращается. В ряде случаев, применяют специальные методы спектрального анализа, например, на халькофильные элементы, на ртуть, анализ с воздушной просижкой пробы в дуге и пр. Эти специальные методы позволяют определять содержания элементов в пробах с большой точностью и уверенно устанавливать даже незначительные отклонения их концентрации от кларков. Для поисков по шлихам и донным осадкам, особенно благоприятны районы с пересеченным рельефом и хорошо развитой гидрографической сетью. В этих же районах перспективно применение гидрохимических методов.

В районах с редкой речной сетью, а также при более детальных

поисках /м.г:10.000 - 1:50.000/ применяют площадные металлометрические поиски, обычно с интервалами опробования по каждому маршруту через 10-50 м. Пробы отбираются в зависимости от обстановки с разной глубины: на участках, где ожидается развитие открытых /выходящих на поверхность/ ореолов месторождений, пробы берутся с поверхности или из-под дернового слоя, на участках с резко ослабленными или погребенными ореолами - с глубины, где регистрация их может быть уверенной. Обычно рыхлые отложения мощностью всего в единицы метров, уже полностью экранируют месторождения и ореолы, препятствуя обнаружению их простейшими разведочными и наземными методами. Такие закрытые для обычных исследований участки, составляют почти нетронутый резерв для поисков многих полезных ископаемых. Суммарная их площадь достигает 60-75% общей территории рудных районов. В связи с сокращением фонда легкооткрываемых месторождений, во многих районах переходят к систематическим глубинным поискам.

Глубинные поиски значительно дороже поисков по поверхности, поэтому они применяются лишь на площадях с надежно установленными геологическими перспективами. Закрытые территории, перед началом работ, дифференцируются по мощности экранирующего рыхлого покрова. Работы начинают преимущественно с участков, где можно ожидать развитие неглубоко погребенных ореолов /порядка 5-10 м/. Здесь относительно проще установить геологическое строение и вести поиски, чем в областях с глубоко погребенными ореолами. Суммарная площадь участков развития неглубоко погребенных ореолов достигает 25-30% общей территории, т.е. сопоставима с открытыми площадями.

Для поисков по неглубоко погребенным ореолам в Советском Союзе созданы и используются специальные станки, позволяющие бурить до 200 мелких скважин в смену и производить комплекс геофизических, геологических и гидрогеологических исследований.

При работах на закрытых площадях, особенно полезно привлечение методов общей геофизики-магнитометрии, гравиметрии, электро-разведки. Последняя используется, в частности, и для определения характера и мощности рыхлых образований.

Поиски каждым из описанных выше методов, завершаются предварительной оценкой объектов с помощью геологических, геофизических и геохимических методов с помощью горными работами и бурением скважин. Обычно, большие трудности представляет оценка сульфидных, урановых и других месторождений, выходы которых подвергаются интенсивным гипергенным изменениям. В этих случаях, масштабы и характер оруденения приходится оценивать не по дневной поверхности, а по представительному горизонту - наиболее близкому к поверхности уровню, отражающему характер оруденения. Иногда представительный горизонт расположен непосредственно под чехлом рыхлых отложений на поверхности коренных пород, а в районах с сохранившейся корой выветривания - на уровне нижней щебенистой ее части, на глубине до 3-5 м. и более от поверхности коренных пород. Представительный горизонт изучается системой мелких преимущественно вертикальных скважин с отбором металлометрических проб с забоя и каротажем. Исследование карна скважин и проб, позволяет уточнить геологическое строение участка, минералогия руд, определить комплекс полезных компонентов, составить металлометрические карты аномальной площади на указанном уровне, определить ее размеры и концентрацию элементов в ее пределах.

Это дает возможность подсчитать на этом уровне количество каждого полезного элемента.

При благоприятных показателях, оруденение прослеживается на глубину, обычно, наклонными глубокими скважинами и затем делается заключение об ориентировочных запасах полезных компонентов и целесообразности продолжения разведочных работ

В разных ландшафтных условиях, описанные методы поисков и оценки, применяются в различных вариантах. Для их определения производится изучение рельефа, покровных отложений, кор выветривания и других компонентов ландшафта с широким использованием аэрофотоснимков. Полученные данные позволяют районировать территории по условиям ведения поисковых работ в различных масштабах, от мелких, используемых для планирования работ в пределах страны, до крупных, для планирования работ отдельных поисковых партий и отрядов. Для каждого выделенного на карте района, устанавливается наиболее эффективный комплекс поисковых методов строго соответствующий геологическим и природным условиям. Такие карты, называемые картами условий ведения поисковых работ, позволяют оценить надежность ранее проведенных поисков, избежать непроизводительных затрат на поиски малоэффективными методами, определить объемы работ и выбрать необходимое оборудование.

Поисковые экспедиции и партии оснащаются современной техникой и оборудованием. Ведущие поисковые методы в Советском Союзе, в основном, базируются на следующей аппаратуре:

При плановой аэрофотосъемке применяются аэрофотоаппараты типа АФА. Аппарат АФА-ТЭУ-100, имеет новый скоростной затвор с экспозицией от $\frac{1}{55}$ до $\frac{1}{500}$ сек. Время цикла - 2,3 мин.

Аппарат снабжен кассетой улучшенной конструкции. Съемка ведется с двухмоторных транспортных самолетов в средних и мелких масштабах /от 1:17.000 до 1:50.000/. Для крупномасштабной съемки с небольших высот, применяется широкоугольный аэрофотоаппарат АФА-36 с фокусным расстоянием 36 мм. Аппарат может быть установлен на одномоторных самолетах, а также на вертолетах.

Аэрогеофизические поиски обычно производятся с помощью комплексной аэрогеофизической станции АСТ-46, которая позволяет непрерывно автоматически измерять приращения модуля вектора T магнитного поля земли, гамма-излучение земли, а также определять природу радиоактивности. Радиометр снабжен счетно-решающей схемой, предназначенной для автоматического введения в результаты измерений поправки за высоту полета.

Чувствительность радиометра 180 имп/сек на 1 мкр/ч. Пределы измерений - 0-22 мкр/ч постоянные времени записи $T_1 = 0,75 \pm 0,1$ сек и $T_2 = 1,5 \pm 0,1$ сек. Канал разделения имеет чувствительность 3-5 имп/сек на 1 мкр/ч /по радиовому эталону/ при коэффициенте разделения $\gamma = 2$; предел измерения - 0-30 мкр/ч.

Магнитометр станции имеет основные пределы измерения $\pm 200 \gamma$ при постоянной 5 γ /мм и $\pm 1000 \gamma$ при постоянной 25 γ /мм. Пределы измерения могут быть расширены до $\pm 6600 \gamma$ и $\pm 11000 \gamma$ автоматическим ступенчатым компенсатором. Начальная компенсация магнитного поля осуществляется в пределах 30000-70000 γ . Порог чувствитель-

ности не более 5 μ . Постоянные времени записи $T_1 = 1,5 \pm 0,1$ сек и $T_2 = 0,75 \pm 0,1$ сек.

Станция АСТ-46 устанавливается в самолете и обслуживается одним оператором.

Для специальных аэромагнитных работ применяется аэромагнитометр АМ-13, имеющий более высокую чувствительность и точность и значительно меньшее смещение нулевой линии. Предусмотрена возможность совместной работы этого прибора с аэрофотоаппаратом. Устанавливается АМ-13 на самолетах с одним или двумя моторами.

При необходимости с самолетов ведутся и электроразведочные работы.

Для аэрогеофизических, геологических аэровизуальных и транспортных целей, советскими геологами широко используются также вертолеты. Применение их позволяет повысить детальность производимых аэрорадиометрических и аэромагнитных поисков, а используя возможность частых посадок, производить поиски с применением гравиметрических, сейсмометрических и других геофизических методов. При работах в удаленных и труднодоступных районах, вертолеты незаменимы для быстрой наземной проверки аномалий, переброски людей, оборудования, полевых лабораторий и пр. В зависимости от задачи, используются тяжелые вертолеты АК-24, средней грузоподъемности МИ-4 или легкие вертолеты - четырехместный Ми-1 и шестиместный Ка-15. Вертолеты позволяют вести работы на абсолютных высотах до 3.000 м.

Геохимические поиски основываются на массовом изучении содержания большого числа элементов в металлометрических пробах на различных спектрографах /ИСП-28, ИСП-51 и др./ Приставка АВР-2/ и ее варианты к этим спектрографам позволяют производить испарение порошков проб непосредственно в пламени горизонтальной угольной или металлической активизированной дуги переменного тока, стабилизированной интенсивным воздушным потоком. При этом происходит одновременное возбуждение спектров всех элементов, независимо от их летучести, что позволяет определить как летучие, так и малолетучие элементы за весьма короткие экспозиции. Воспроизводимость спектральных анализов повышается в 2-3 раза, существенно снижается себестоимость анализов.

Полевое определение содержания многих элементов /с 30 - 80/ на рудных участках производится с помощью прибора РАП-3 новым рентгенометрическим методом. Этот метод основан на регистрации с помощью сцинтилляционной аппаратуры характеристического излучения атомов, возбуждаемого радиоактивным излучением тулия -170. Вес прибора - 15 кг., питание от батарей, порог чувствительности - 0,01-0,1%. Полевые лаборатории позволяют микрохимически определять ниобий, тантал и другие трудно диагностируемые элементы.

Для полевых радиометрических измерений используется сцинтилляционный радиометр СРП-2 весом 2,7 кг. Диапазон измерения интенсивности гамма-излучения до 2500 мкр/час. Постоянные времени прибора 1,5 и 5 сек., чувствительность при $T = 5$ сек - 1,5 мкр/ч. Высокая чувствительность и компактность прибора способствуют широкому его внедрению. Возможность производить с его помощью замеры в мелких скважинах /шпурах/ позволила в лесных и других районах с выщелоченными почвами, применить гамма-шпуровую съемку,

заменяя ее эманационную. В этих же районах при наземных поисках крутопадающих рудных тел сульфидных и других месторождений, хорошие результаты показал портативный электроразведочный прибор ИА /искатель жил/.

Для поисков свинца, вольфрама, ртути и других элементов с большим массовым числом, применяется гамма-гамма-каротаж /ГГК/, а для поисков бериллиевых руд - методы, основанные на использовании фото-нейтронного эффекта.

Лабораторные радиометрические измерения производятся приборами ЛСУ-5к и РАД-1. Пятиканальная лабораторная спектрометрическая установка ЛСУ-5к предназначена для определения в пробах порог чувствительности по α и β -лучам, по К -С, 2%. РАД-1 позволяет производить радиохимические анализы слаборадиоактивных проб на α и β , а также оценивать α -активность порошковых проб с кларковыми /и выше/ содержаниями.

Для определения нейтронно-абсорбционным методом при содержании их в пробах 0,01% и выше, предназначен прибор РАД-2 /нейтрон/.

Концентрация различных элементов в образцах пород, почв, растений и вод определяется с помощью и других приборов, а также полевых, полустационарных и стационарных химико-аналитических лабораторий. Пробы, при необходимости, подвергаются также минералогическому, рентгено-структурному, термическому и другим видам анализа.

Отбор проб при поисках на закрытых площадях производится с помощью переносных и самоходных буровых станков. Примером самоходной гусеничной установки, предназначенной для массовых поисков по неглубоко погребенным ореолам, является СУП-10. Станок основан на принципе гидравлического задавливания бурового снаряда. Специальный прободоотборник позволяет брать пробы с заданной глубины. В процессе проходки скважин осуществляется автоматический гамма-каротаж. Производительность установки в песчаных и суглинистых породах около 600 м. в смену при глубине скважин 8 м. и около 360 м. при глубине 25 м. Еще большую производительность дают вибрационные самоходные установки типа СВА-2.

В горных и лесных районах применяется переносный механический прободоотборник МП-1. Пустотелый шнек позволяет производить опробование и каротаж скважин в неустойчивых породах. Вес прободоотборника - около 16 кг., производительность - до 250 скважин глубиной 1,5 - 3,0 м. в смену.

Технический прогресс в различных областях народного хозяйства СССР обеспечивает дальнейшее быстрое развитие технического оснащения геологоразведочных работ.

В заключение следует подчеркнуть, что приступая к поискам, нужно иметь в виду и максимально использовать возможность обнаружения данным методом не одного, а обычно многих различных видов минерального сырья. В частности, это позволяет быстро определить круг полезных ископаемых изучаемых территорий, что особенно важно для наименее изученных районов. В случаях необходимости, вести специализированные поиски на определенный вид полезного ископаемого возможно, для большей уверенности, применять не один, а комплекс методов. Например, для поисков алмазов могут быть использованы методы дешифрирования аэрофотоснимков, аэро- и наземные геофизические методы и шлиховой; для поисков золота - помимо только что указанных - также геохимический; для поисков железа - магнитометрический и шлиховой и т.д. Однако, в любом случае, необходимо соблюдать принцип максимальной экономии средств, что достигается знанием возможностей методов и природной /геологической и ландшафтной/ обстановки, в которой ведутся поиски.



**CONFERENCIA DE LAS NACIONES UNIDAS
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**EVALUACION
DE LOS RECURSOS HIDRAULICOS SUPERFICIALES**

**Por Eduardo CRAVIOTO GUERRERO,
Ingeniero,
Director de Hidrología**

Las monografías presentadas en la Conferencia de las Naciones Unidas sobre la Aplicación de la Ciencia y la Tecnología en Beneficio de las Regiones Menos Desarrolladas constituyen documentos de trabajo de dicha Conferencia. Se publican tal como han sido presentadas por los colaboradores y los puntos de vista expresados en ellas corresponden a los colaboradores. (Véanse notas al dorso.)

NOTAS

1. Las monografías seleccionadas para las Sesiones Generales serán distribuidas en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

2. Las monografías seleccionadas para las Sesiones Especiales serán distribuidas en la Conferencia únicamente en uno de los idiomas oficiales antes indicados.

3. Los resúmenes de las monografías presentadas por los colaboradores serán distribuidos en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

4. No se procederá a la distribución general de las monografías y resúmenes con antelación a la Conferencia. Únicamente serán publicadas en cantidades limitadas con antelación a la Conferencia para uso exclusivo de las delegaciones de los gobiernos participantes y de otros participantes autorizados. La publicación con posterioridad a la Conferencia y la distribución general de las actas y debates de la Conferencia seguirán las prácticas de las Naciones Unidas establecidas por la Junta de Publicaciones de las Naciones Unidas.

EVALUACION DE LOS RECURSOS HIDRAULICOS SUPERFICIALES

Por el Ing. Eduardo Cravioto Guerrero.- Director de Hidrología

I.- PREAMBULO

1.- La evaluación de los recursos hidráulicos superficiales es sumamente importante para una correcta planeación del mejor aprovechamiento de las corrientes, -- coordinando los diversos usos en la forma más adecuada y conveniente, tanto desde el punto de vista regional como nacional.

2.- Estando nuestro país en desarrollo, todos los gobiernos se han preocupado por ampliar dentro de sus posibilidades, la red de estaciones climatológicas y pluviométricas o hidrométricas, sin embargo aunque a la fecha se tiene un número considerable de estaciones todavía será necesario instalar aún más en los próximos -- años para poder hacer una evaluación lo más fidedigna posible, de nuestros recursos hidráulicos superficiales.

II.- CICLO HIDROLOGICO.

3.- Se denomina ciclo hidrológico al proceso continuo que siguen las partículas de agua desde que se precipitan en forma de lluvia, nieve granizo, etc. para después escurrir superficial o subterráneamente, almacenarse en los mares, lagos naturales y artificiales y después evaporarse para aumentar la humedad de la atmósfera y estar en condiciones de volver a precipitarse. Este capítulo se refiere a la forma en que se miden o estiman en México, las principales fases del ciclo hidrológico.

4.- Medición de la precipitación.- En México prácticamente toda la precipitación del vapor de agua es en forma de lluvia y únicamente en algunos estados del -- norte y noroeste se tienen nevadas de alguna consideración, pero aún en estas zonas el porcentaje de nieve con relación a la precipitación total es muy reducido y por lo tanto su estudio carece de importancia en este País.

5.- La mayoría de los pluviómetros usados tienen un vaso medidor de 7.1 cm de -- diámetro por 20 cm de altura por lo que fácilmente pueden registrarse láminas de -- lluvia de 20 mm, sin embargo como el vaso medidor está dentro de un depósito que -- tiene 23 cm de diámetro y 29.6 cm de alto en realidad pueden registrarse láminas de lluvia hasta de 300 mm, únicamente que esta medida ya no es directa, habiendo necesidad de determinarla en función de la capacidad del vaso medidor. En algunos lugares de precipitación intensa, actualmente se están instalando pluviómetros con un -- depósito de mayor altura para poder registrar lluvias de más de 300 mm en 24 hrs. -- que es el lapso de tiempo en que se hacen las observaciones.

6.- Se tienen en operación pluviógrafos de diferentes marcas, pero la mayor parte son "Fuess" o "Lambrecht" que siguen el sistema de sifón del profesor Hellman, -- siendo relativamente reducidos en número, debido a su alto costo en comparación con el del pluviómetro y a que se necesita personal algo más preparado para su atención.

7.- Medición del escurrimiento superficial.- El escurrimiento superficial es -- aquella parte de la lluvia caída en los continentes que escurre por los cauces de -- los arroyos y ríos. La mayor parte del escurrimiento superficial se origina al -- afluir el agua de lluvia directamente en los cauces debido a que la intensidad de -- la lluvia durante las tormentas es superior a la rapidez de infiltración ó a que el

suelo se encuentre ya saturado por la infiltración ocurrida por lluvias anteriores, - en cuyo caso se facilita el escurrimiento rápido en forma de grandes crecientes. Una parte del agua infiltrada en el terreno reaparece posteriormente aguas abajo en forma de manantiales o veneros, aumentando el escurrimiento superficial principalmente en el estiaje, por lo que a pesar de no registrarse lluvia en alguna época del año, - se tienen escurrimientos en algunos ríos durante todo el año.

8.- Para la medición del caudal de las corrientes superficiales se han establecido estaciones hidrométricas o fluviométricas en donde constantemente se miden las fluctuaciones del nivel del agua y en algunos casos se determinan los gastos para diferentes niveles. En corrientes naturales y pequeñas se han instalado vertedores o medidores Parshall en donde con solo medir los niveles se calcula el gasto con fórmulas teóricas que en algunos casos se han comprobado prácticamente. En los ríos o arroyos el método más comúnmente usado es el de sección y velocidad que consiste en hacer sondeos en cada caso para conocer la sección y en medir la velocidad del agua por medio del molinete hidráulico.

9.- Para conocer perfectamente las fluctuaciones del nivel del agua se ha procurado instalar aparatos registradores o limnigrafos en la mayoría de las estaciones hidrométricas y en donde no se tienen, se hacen lecturas de escala cada 6 horas y durante las crecientes a menor intervalo de tiempo según la magnitud del caudal del río.

10.- Para hacer los sondeos y determinación de la velocidad se usan los métodos siguientes:

a).- Vadeo. - En corrientes pequeñas o durante el estiaje en corrientes más grandes, el aforador se mete al cauce del río para hacer sus mediciones, pero esto solo puede hacerse en los casos en que se tienen láminas de agua de menos de 0.80 m y velocidades de menos de 1 m/s.

b).- Pasarelas o puentes. - Para aforar corrientes más grandes se instalan pasarelas o puentes en los sitios adecuados o se utilizan puentes carreteros o de ferrocarril ya construidos, aunque éstos no siempre son adecuados, sobre todo cuando tienen varias pilas intermedias o están muy esviados.

c).- Cablevía. - La experiencia ha indicado que en claros de más de 20 m. lo más recomendable económicamente, es tender un cablevía para el paso de una canastilla -- desde donde se hacen los sondeos y las mediciones de la velocidad por lo que en nuestro país la mayoría de las estaciones son de este tipo.

d).- Canoa. - En cauces sumamente anchos de poca velocidad y que no son apropiados para construcción de cable y canastilla, se hacen los aforos en canoa, tendiendo un cable para sostenerla. Las estaciones que tenemos de este tipo son muy reducidas y se localizan en algunos ríos caudalosos del sur de la Vertiente del Golfo.

11.- Medición de la evaporación en la superficie libre del agua. - Se usan los evaporímetros terrestres ligeramente separados del suelo, que son los más comúnmente usados en los Estados Unidos y el que provisionalmente ha recomendado como oficial la Organización Meteorológica Mundial, consistiendo en un tanque de 122 cm de diámetro (4 pies) y 26 cm de alto, en el que se tiene un cilindro de reposo y un tornillo micrométrico con el que se mide la lámina evaporada, haciéndose las observaciones diariamente a las 8 hrs.

12.- Medición de la evapotranspiración. - Se han instalado algunos evapotranspirómetros que consisten esencialmente en un depósito de agua que alimenta un pequeño tanque en donde se conserva un nivel constante por medio de una llave de flotador y vertedero. Este último tanque alimenta a un receptáculo cilíndrico enterrado en el suelo hasta sus bordes y colocado a su mismo nivel, que tiene grava abajo y está lleno de tierra hasta el nivel del terreno circunvecino en donde se siembran las plantas adecuadas. La cantidad de agua utilizada en mantener constante el nivel del agua es la que mide la evapotranspiración. Sin embargo a la fecha no se han podido obtener buenas conclusiones, por lo que hay necesidad de estimar la evapotranspiración por los métodos de Lowry-Johnson, Blayney, y C.W. Thornthwaite, siendo este último el más comúnmente usado.

III.- PRECIPITACION PLUVIAL.

13.- La lluvia es producida por la condensacion de parte del vapor de agua contenido en la atmósfera y se debe a un enfriamiento de las masas de aire humedo que hace que se saturen y el agua excedente se precipita en forma de lluvia principalmente y resulta por cualquiera de las siguientes causas o su combinacion: a-por -- corrientes convectivas, b-por topografia, c-por perturbaciones ciclónicas y d-por choque de grandes masas de aire. La lluvia orográfica ó de relieve es la que más -- se presenta debido a que nuestro país tiene un relieve muy accidentado existiendo cadenas de montañas casi paralelas a las costas, tanto en el Pacífico como en el -- Golfo de México. Sigue en importancia la lluvia ciclónica ya que la República Me-- xicana se encuentra expuesta a los ciclones del Atlántico, principalmente los gene-- rados en el Caribe y a los del Pacífico, los que cuando afectan el País producen -- fuertes precipitaciones que a su vez ocasionan crecientes en los rios. Las lluvias por choques de masas de aire se registran en el norte y más comunmente en el no-- roeste en donde han provocado las máximas crecientes en algunos rios.

14.- Red de estaciones pluviométricas.- Varias son las dependencias oficiales que tienen en operacion estaciones climatológicas, instalándolas en los lugares que son necesarios para sus respectivas actividades, lo que ha dado como resultado que haya zonas del País, como en el centro de la República, en donde se tienen relativamente numerosas estaciones y en cambio en otras zonas menos pobladas como son -- las Penínsulas de Yucatán y Baja California, se tenga escasez de datos. Sin embar-- go la Secretaría de Recursos Hidráulicos ha procurado dentro de las limitaciones -- presupuestales, llenar las lagunas existentes para así poder conocer mejor cada -- día los recursos hidráulicos de nuestra nación. La mayoría de las estaciones solo constan de pluviómetro en donde se hacen las observaciones cada 24 hrs. y solo -- en algunas se tiene además, pluviógrafo para medir las intensidades de lluvia.

15.- En el presente año de 1962 se tienen establecidas 1373 estaciones pluviométricas operadas por la Secretaría de Recursos Hidráulicos y 844 por las demás -- oficinas, haciendo un total de 2217 estaciones, repartidas en los diferentes esta-- dos en la forma siguiente:

TABLA NUM. I

Z o n a	Estados que comprende	Sup.en Km2	No.de est.	Km2.por est.
Pacífico Norte	B.California, Territorio de B.California, Nayarit Sinaloa y Sonora.	414 437	287	1 444
Norte	Coahuila, Chihuahua, Durango, N. León, San Luis Potosí, Tamaulipas y Zacatecas.	800 578	610	1 312
Centro	Aguascalientes, Distrito Federal, Guanajuato, Hidalgo, Jalisco, México, Michoacán, Morelos, Puebla, Querétaro y Tlaxcala.	274 669	726	378
Golfo de México	Campeche, Q. Roo, Tabasco, Veracruz y Yucatán.	238 999	262	912
Pacífico Sur	Colima, Chiapas, Guerrero y Oaxaca.	238 500	332	718
Total		1 967 183	2 217	887

16.- Esta tabla muestra que en los estados del centro se tiene la red más nu-- rosa de estaciones, pero en las otras zonas y sobre todo las del norte el número -- de estaciones es escaso. Para tener una estación pluviométrica cada 500 Km2 en pro-- medio como mínimo en cada zona, que seria lo deseable, será necesario instalar -- 1 900 estaciones más.

17.- La lluvia media anual en la República Mexicana.- En la figura 1 se mues-- tran las curvas isoyéticas en la República Mexicana, el cual está basado en las --

lluvias registradas en todas las estaciones con un período de datos no menor de -- 10 años. En este plano puede verse que las zonas más lluviosas con precipitaciones de más de 1 500 mm se localizan en los estados de Chiapas, Tabasco, Veracruz, Oaxaca y la región noreste de los estados de Puebla e Hidalgo y las zonas más áridas -- se tienen en los estados del norte, San Luis Potosí, Zacatecas, Durango, Coahuila, Chihuahua, Sonora y Baja California. En la misma figura 1 se muestran las lluvias -- medias mensuales en algunos lugares de las diferentes zonas hidrológicas, las que -- indican claramente el monto y la distribución de las mismas.

18.- Las superficies con lluvia igual o mayor a una lluvia dada son las siguientes:

TABLA NUM. 11

Lluvia media	Porciento de la superficie con lluvia igual o superior a la indicada en la 1a. columna.	Porciento de la superficie con lluvia inferior a la indicada en la 1a. columna.
3 000	0.6	99.4
2 000	2.9	97.1
1 000	23.1	76.9
717	41.9	58.1
500	57.2	42.8
400	68.7	31.3

19.- Estos datos indican que solo en el 23.1% del área de la República se tiene una lluvia media anual de un metro o más y en el resto o sea el 76.9% es menor; en el 41.9% del área la precipitación es igual o superior a la media en la República, y en la tercera parte del país las lluvias son muy escasas inferiores a 400 mm anuales.

20.- Métodos seguidos para la extrapolación de datos pluviométricos. -- Para una correcta evaluación de los recursos hidráulicos superficiales, el mejor procedimiento consiste en la medición directa de los escurrimientos por un largo período de tiempo que cubra tanto años de abundancia como de escasez, sin embargo en la -- República Mexicana solo en algunos casos se tienen estadísticas hidrométricas suficientes. En la mayoría de los casos la ampliación del período de datos hidrométricos se hace basándose en las lluvias por lo que en primer lugar hay necesidad de -- completar los datos pluviométricos.

21.- Cuando solo faltan algunos meses de la época de estiaje, se considera suficiente calcular el promedio registrado en dicho mes en los años con observaciones, ya que por lo general las lluvias en estiaje son muy reducidas. Cuando faltan algunos meses de la época de lluvias, se deduce por el método racional deductivo, -- el que se basa en la suposición de que la lluvia mensual está en relación directa de la lluvia anual ó sea que depende de si el año es escaso, normal o abundante. -- Este método no se usa cuando en el mes o meses faltantes se tuvieron lluvias excepcionales en las estaciones vecinas en cuyo caso se usa el método de correlaciones.

22.- Para estimar datos faltantes también se usa el método de correlaciones -- gráficas entre los datos mensuales de la estación con registros incompletos y los de algunas estaciones cercanas con datos completos, aceptando la relación que queda mejor definida o con promedios de 2 ó 3 estimaciones.

23.- El método racional y el de correlaciones también se utilizan para la estimación de lluvias anuales, con el fin de completar un período común de datos en todas las estaciones seleccionadas en una cuenca. Para la aplicación del método racional se escogen las estaciones con el período de datos completo a las que se les denomina "estaciones piloto" y en función de estas se estiman los datos faltantes en las estaciones vecinas.

IV.- ESCURRIMIENTO SUPERFICIAL.

24.- La precipitación pluvial en una cuenca hidrográfica, se distribuye en varias partes, una se infiltra en las capas más profundas, otra es absorbida por --

las raíces de las plantas, otra parte se pierde por evaporación en el suelo y en los almacenamientos superficiales y el resto escurre superficialmente por los cauces de los arroyos y ríos.

25.- El escurrimiento superficial depende de muchos factores, siendo los principales los siguientes: a) régimen pluvial, no solo la cantidad total de lluvia -- sino sus intensidades y distribución en la cuenca; b) posición de la cuenca con relación a las fuentes de humedad; c) topografía, área, forma y pendiente de la cuenca; d) geología; e) vegetación y f) almacenamientos naturales y artificiales.

26.- La cantidad de agua escurrida por los ríos y arroyos mexicanos es sumamente variable, no únicamente durante el año sino también de un año a otro, siendo la mayoría de régimen torrencial, registrándose fuertes escurrimientos en unos meses en la temporada de lluvias y muy bajos o nulos en la temporada de secas -- teniendo además períodos de años lluviosos y períodos de años escasos, por lo que para conocer el régimen de las corrientes es indispensable medir el escurrimiento superficial durante muchos años, pues con un corto período de datos no se tendría suficiente información.

27.- Red de estaciones hidrométricas..- En los párrafos Nos 8, 9 y 10 se trató brevemente acerca de las diferentes clases de estaciones hidrométricas establecidas en México para la medición de los escurrimientos superficiales en las corrientes naturales, mencionándose que el método más comúnmente usado es el de sección y velocidad, haciéndose los aforos en la mayoría de las grandes corrientes, desde -- una canastilla que corre sobre un cable vfa y en las pequeñas desde una pasarela. -- Para medir las fluctuaciones del nivel del agua se utilizan limnigrafos en las estaciones de la clase y simplemente escalas en las de 2a. clase en las que se hacen observaciones a las 6, 12 y 18 hrs, salvo en el caso de crecientes que se hacen cada hora, sin embargo actualmente se tiene la tendencia a instalar todas las estaciones con limnigrafo por ser lo más apropiado. En corrientes con fluctuaciones considerables del nivel del agua y con un cauce con taludes muy tendidos que hacen cara la instalación y muy difícil la operación de un limnigrafo común, se están empezando a instalar los llamados "limnigrafos de burbuja" que registran las variaciones del nivel del agua en función, de las variaciones de la carga de presión, transmitida por medio de gas o aire comprimido, las cuales las registra un -- limnigrafo reversible muy sensible que marca la gráfica "Presión-Tiempo", que a -- determinada escala es semejante a la gráfica "tirante-tiempo".

28.- Como en el caso de las estaciones climatológicas, también hay varias dependencias oficiales que operan estaciones hidrométricas, teniendo actualmente 1103 estaciones hidrométricas de las cuales 729 están sobre ríos o arroyos, 270 sobre canales principales y 104 en presas de almacenamiento. Teniendo en cuenta la superficie total de la República y descontando las correspondientes a canales, se tiene una estación por cada 2 400 Km² ó sea que a pesar del incremento que han tenido esta clase de instalaciones, todavía hay mucho por hacer para tener por lo menos una estación por cada 1 500 Km² en promedio.

29.- Régimen de escurrimiento de las corrientes mexicanas..- La forma alargada y angosta de la República Mexicana y su relieve accidentado con cadenas de montañas paralelas a los litorales, origina que la mayoría de los ríos sean de corta -- longitud y fuerte pendiente y como además las lluvias se concentran en unos meses del año, el régimen de la mayoría de las corrientes es torrencial. Por lo general la época de avenidas es de junio a octubre ó sean 5 meses y el estiaje en los 7 meses de noviembre a mayo en que se secan por completo o solo llegan gastos muy reducidos. En el noroeste debido a las lluvias de invierno producidas por el choque de masas de aire frío del norte con masas de aire caliente y húmedo del sur, en algunos años se tienen avenidas en los meses de diciembre a febrero que en algunas corrientes han provocado las avenidas con gastos más altos, pero los gastos medios mensuales son inferiores a los de verano. En la Vertiente del Golfo, en donde se tiene una mayor humedad, los gastos de estiaje son de alguna importancia y en los ríos de la zona húmeda del país ó sea en el Sureste los gastos de estiaje son de bastante consideración y así por ejemplo en el río Usumacinta el mínimo es de más de 500 m³/s.

30.- También varían considerablemente las aportaciones de un año a otro, prin-

principalmente en las corrientes de la zona seca del norte, teniendo muchas de ellas - un régimen muy errático. La mayor variación en los escurrimientos anuales se ha observado en el Rfo Tijuana, localizado en el extremo noroeste de la Península de la Baja California, en donde el escurrimiento medio anual de 1938 a 1961 ha sido de - 22.9 millones de m³ con un máximo en 1941 de 216 millones de m³ y un mínimo de 0.5 millones de m³ ó sea una variación del máximo al medio de 9.4 y del máximo al mínimo de 432.

31.- En la Altiplanicie también el régimen de las corrientes es variable aunque no tanto como en el rfo Tijuana antes mencionado y así en la cuenca cerrada -- del rfo Nazas hasta la presa Lázaro Cárdenas, de 1929 a 1961 se ha tenido un escurrimiento medio anual de 1 100 millones de m³ con un máximo de 2 452 en 1938 y un mínimo de 279 en 1929 ó sea una variación del máximo al mínimo de 8.8.

32.- En la zona húmeda las variaciones son de menor consideración, por ejemplo en el rfo Grijalva en la estación de Las Peñitas, aguas abajo de donde actualmente se construye la presa de Malpaso que será la mayor de la República, el escurrimiento medio anual de 1945 a 1961 es de 21 000 millones de m³, con un máximo de 34 800 millones de m³ en 1955 y un mínimo de 13 800 millones de m³ en 1946 ó sea una relación del máximo al mínimo de 2.52.

33.- Para dar una idea del régimen de las corrientes superficiales mexicanas - se preparó la Figura II en donde pueden verse los escurrimientos medios mensuales de algunos ríos entre ellos los mencionados en los párrafos 30, 31 y 32.

V.- EVALUACION DE LOS RECURSOS HIDRAULICOS SUPERFICIALES.

34.- La evaluación correcta de los recursos hidráulicos superficiales debe hacerse midiendo directamente las aportaciones de las subcuencas de cada una de las diversas cuencas de captación de una nación. Sin embargo aún en países económicamente fuertes, es imposible tener una red de estaciones que cubra todas las subcuencas y en países de economía más reducida, como México, solo es posible medir los escurrimientos de las más importantes o de aquellas en las que se tiene un proyecto de aplicación inmediata para aprovechamiento en algún uso benéfico. Por lo anterior en muchos casos no se dispone de datos o cubren un período reducido de tiempo que hay necesidad de ampliar para tener un mejor conocimiento de su régimen.

35.- Como por lo general en México se tiene una mayor información pluviométrica que hidrométrica, el método comúnmente usado para la extrapolación de datos hidrométricos es por medio de la lluvia media en la cuenca y el coeficiente de escurrimiento, aunque en algunos casos cuando es posible, se hace la extrapolación por medio de correlaciones con datos de cuencas vecinas.

36.- Extrapolación de datos hidrométricos por medio del coeficiente de escurrimiento. - Cuando se tienen varios años de datos hidrométricos y un amplio período de datos pluviométricos, la extrapolación se hace determinando primero la lluvia media en la cuenca para cada ciclo considerado y posteriormente el coeficiente de escurrimiento o sea la relación entre el volumen escurrido y el volumen llovido en la cuenca correspondiente. La lluvia media en la cuenca se determina por dos procedimientos: trazando curvas isoyéticas o de igual lluvia o por medio de áreas de influencia o método de Thiessen. El primer procedimiento tiene la ventaja de que al trazar las curvas se puede tomar en cuenta el aspecto orográfico teniendo gráficas que se apegan lo más posible a la realidad, por lo que las lluvias medias estimadas por este método es de lo más preciso posible. El segundo método no toma en cuenta el relieve de la cuenca, pero los resultados son bastante aproximados y sobre todo es muy práctico ya que teniendo el mismo período de datos en todas las estaciones, ya sean registrados o estimados, una sola vez se determinan las áreas de influencia y rápidamente se pueden calcular las lluvias medias para cada uno de los ciclos de estudio.

37.- También se estiman las lluvias medias anuales en una cuenca con el siguiente procedimiento que es una variante del primer método antes mencionado. Se trazan las curvas isoyéticas medias anuales correspondientes a todo el período en que se dispone de datos pluviométricos y se determina la lluvia media localizándose después varias estaciones que tengan el mayor número de datos observados y que se en-

cuentren bien distribuidos en la cuenca denominándose estaciones piloto. Basándose en los datos de estas estaciones piloto se determinan los porcentajes de la lluvia de cada año con relación a la media anual de todo el período de estudio, con los -- que se obtiene la lluvia media para cada uno de los años. Este procedimiento tiene la ventaja de disponerse de las curvas isoyéticas medias que ilustran claramente -- las condiciones pluviométricas de las diferentes zonas de la cuenca, además de ser rápida aplicación para el cálculo de las lluvias de cada año o de cada ciclo que se considere.

38.- Una vez determinada la lluvia media por cualquiera de los métodos antes -- mencionados, se investiga la relación que existe entre la lluvia y los escurrimientos. El procedimiento más sencillo consiste en encontrar la relación gráfica entre la lluvia media y el coeficiente de escurrimiento correspondiente en los años en -- que se tienen observaciones hidrométricas, que es la ley o relación del coeficiente de escurrimiento, la cual por lo general es una curva, siendo suficiente trazarla -- gráficamente. Con la relación del coeficiente de escurrimiento y las lluvias medias, se hace la extrapolación de los datos hidrométricos teniéndose así un período de -- datos de escurrimientos semejantes al de datos pluviométricos.

39.- Cuando solo se dispone de datos pluviométricos de una cuenca, pero se tiene una cuenca vecina con datos pluviométricos e hidrométricos, se usa como guía la ley del coeficiente de escurrimiento de esta última y se aplica a los datos de la -- primera, pero haciendo los ajustes que se crean convenientes por las diferencias -- que se tengan en las características de las dos cuencas, aunque como es natural, es -- tos ajustes dependen en gran parte del criterio personal del ingeniero hidrólogo en -- cargado del estudio.

40.- Extrapolación de los datos hidrométricos por medio de correlaciones. - En -- los casos en que se tienen algunos datos hidrométricos de la cuenca en estudio y un -- amplio período de datos en una cuenca vecina en donde se tengan condiciones meteorológicas parecidas, se usa un método rápido y sencillo que consiste en determinar la -- relación gráfica entre los volúmenes escurridos en las dos cuencas, utilizándose -- esta gráfica para la extrapolación de los datos. Estas relaciones se hacen con datos -- mensuales o anuales, obteniéndose muy buenos resultados cuando queda bien definida -- la relación. También se usa el mismo procedimiento con estaciones hidrométricas de -- una misma cuenca cuando esto es posible.

41.- En los casos en que no se dispone ni de datos hidrométricos ni pluviométricos, se utilizan las aportaciones por Km² calculadas para cuencas lo más cercanas -- posible y teniendo en cuenta las condiciones de las cuencas, principalmente magnitud -- forma y orografía, pero la aproximación de estas estimaciones depende en gran parte -- del criterio personal del ingeniero que las hace.

42.- Los métodos mencionados para extrapolar el período de datos pluviométricos e hidrométricos son los más usuales en México, pero en algunos casos se siguen otras -- variantes, dependiendo de la información y tiempo disponible para el estudio.

43.- Siguiendo los métodos anteriores se ha hecho la siguiente estimación preliminar de los recursos hidráulicos superficiales en la República Mexicana:

TABLA NUM. III

Zona	Volumen medio anual escurrido en millones de m ³ .
Península de Baja California	574
Vertiente del Pacífico	
Zona norte	48 496
Zona sur	63 948
Altiplanicie	8 931
Vertiente del Golfo	
Zona norte	52 682
Zona sur (incluye R. Usumacinta)	174 967
Península de Yucatán (incluye R. Hondo)	4 981
	354 571

Como se nota en esta tabla, casi el 50% de los recursos se concentra en la zona lluviosa del sur de la Vertiente del Golfo de México, correspondiente a las cuencas de los ríos Papaloapan, Coatzacoalcos, Tonala, Grijalva y Usumacinta en donde se tiene una aportación media anual unitaria de 910 000 m³/Km². En el resto de la República esta aportación varía desde 5 600 m³/Km²., en algunos ríos de Baja California y noroeste de Sonora hasta 2 600 000 m³/Km²., en algunos ríos del sur del estado de Chiapas.

VI.- INUNDACIONES Y CONTROL DE AVENIDAS.

44.- Estando expuesta la República Mexicana a los ciclones del Atlántico y del Pacífico, estos han ocasionado la mayoría de las grandes crecientes e inundaciones aunque también se han registrado por otras causas.

45.- En los últimos años se han registrado varias inundaciones siendo las principales las siguientes:

a) En el año de 1954 el río Bravo llevó una gran creciente que inundó varias poblaciones fronterizas importantes como Nuevo Laredo y Piedras Negras. El gasto máximo en Cd. Acuña fue de 35 000 m³/s que es más del doble del máximo registrado en las demás corrientes de nuestro País.

b) El río Pánuco en 1955 inundó por más de un mes el puerto de Tampico y otras poblaciones menores, siendo el volumen de la creciente en 37 días de 24 000 millones de m³. que es el 150% de volumen medio anual.

c) En septiembre de 1958 por el río Lerma escurrió una creciente extraordinaria que provocó inundaciones en todos los valles y poblados ribereños que duraron más de un mes.

d) En enero de 1960 ocurrieron grandes crecientes en los ríos del noroeste que inundaron las zonas bajas. La presa M. Hidalgo, sobre el río Fuerte, derramó un gasto de 8 000 m³/s que es el máximo derramado a la fecha por una presa mexicana.

e) El ciclón registrado en octubre de 1959 en el Pacífico, al entrar a tierra provocó crecientes extraordinarias en los ríos Cihuatlán y Coahuayana, con gastos unitarios de 9.85 y 2.35 m³/s/Km² para cuencas de 1 370 Km² y 7 230 Km² respectivamente, gastos que son superiores a los de la envolvente mundial de gastos máximos de Creager para C=100.

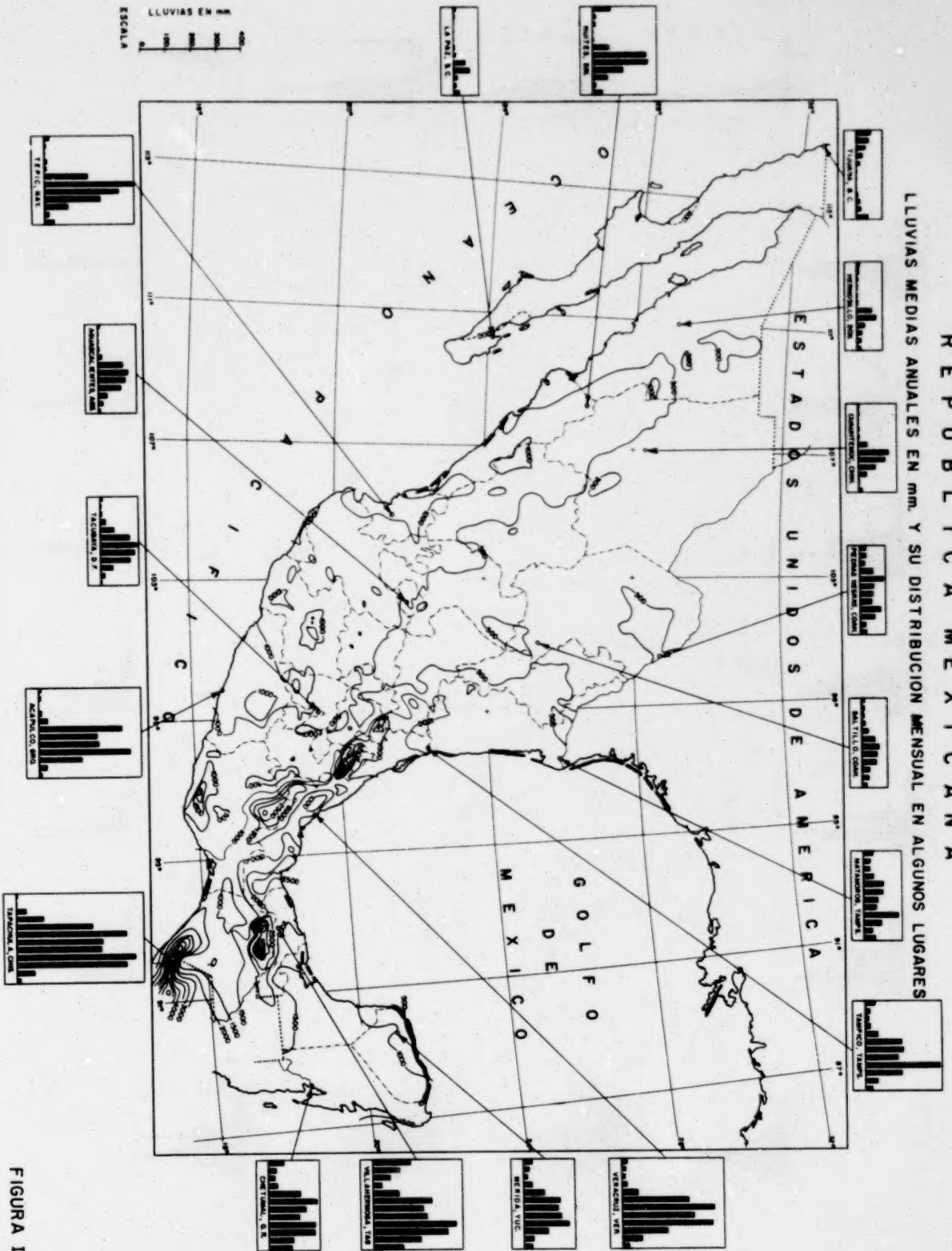
46.- Control de avenidas. Para los estudios de control de avenidas en presas de almacenamiento se toma como base la avenida máxima ordinaria, que es la máxima registrada en un período adecuado de datos no menor de 25 años. Cuando se tiene un período reducido de datos de avenidas se hace una extrapolación basándose en comparaciones con los datos de cuencas vecinas o en función de los datos de las tormentas registradas y aplicando el método del hidrógrafo unidad, aunque esto no siempre es posible.

47.- Cuando no se dispone de datos hidrométricos, la avenida máxima ordinaria se estima con envolventes de gastos máximos de la zona o en función de las intensidades máximas de las lluvias medias registradas en la cuenca y aplicando la fórmula de Arnold y Gregory que toma en cuenta, además de la lluvia, la magnitud, forma y pendiente de la cuenca y características del cauce.

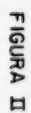
48.- Actualmente en casi todas las presas de almacenamiento de uso múltiple, se deja una capacidad reservada exclusivamente para control de avenidas, la cual se fija estudiando el paso de la avenida máxima ordinaria por varias alternativas de obras de control considerando un gasto máximo de salida semejante al que puede pasar por las zonas bajas sin provocar inundaciones, en unos casos en las condiciones naturales del cauce y en otras considerando bordos de defensa para aumentar su capacidad. Por lo general, al final de la época de avenidas, cuando va disminuyendo el peligro de grandes crecientes, se permite almacenar agua para algún uso benéfico, aprovechando parte de la capacidad para control de avenidas.

REPUBLICA MEXICANA

LLUVIAS MEDIAS ANUALES EN MM. Y SU DISTRIBUCION MENSUAL EN ALGUNOS LUGARES



GASTOS MEDIOS MENSUALES EN m³/seg. EN ALGUNAS CORRIENTES SUPERFICIALES





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NEW STEPS TOWARDS BETTER DATA
AND INVESTIGATION
FOR WATER RESOURCES DEVELOPMENT

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NEW STEPS TOWARD BETTER DATA AND INVESTIGATION FOR WATER RESOURCES DEVELOPMENT

by

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Introduction

1. We have learned that the way in which we develop water resources affects the good or ill of mankind. Flow regulation can provide water for irrigation, control floods, or generate power. On the other hand, irrigation can generate salinity problems; the construction of a dam induces changes in river morphology, and the consequences of these changes are costly. Some effects are slow and subtle. Pumping of ground water sooner or later restricts use of river water.
2. Knowledge of such causes and effects -- part of today's slowly gained learning about water development -- is small indeed compared with the vast objectives and problems that lie ahead. To obtain water one must know the environment, and this knowledge is obtained through hydrologic data and study.
3. The domain of man's activity transects all arcs of the water circle. Hydrologic data are therefore of many kinds -- observations of precipitation, snow cover, surface water, ground water, sediment transport, chemical quality, evaporation, soil moisture, and many others. The certainty of this need for hydrologic data in the accelerating water development throughout the world has created a growing interest in improving methods for collecting these records, for their interpretation, and for their use in solving problems. To illustrate these techniques, we have focused attention on some of the principal hydrologic data on precipitation, surface water, and ground water.
4. Hydrologic observations provide data for many purposes, all of which need to be considered in planning a program. On the other hand, it is not possible to anticipate the nature of all future hydrologic inquiries. Moreover, one cannot afford to defer the collection of hydrologic data or the launching of hydrologic studies until specific questions arise for specific areas and problems. Time--often years--is required to collect adequate data. Experience has proved the necessity for a core program, as in a national basic network that is adaptable to the solution of a wide variety of problems. Methods will be described for the design of such networks.

Precipitation

5. As the source of all fresh water, precipitation is an important hydrologic factor. It is at once the easiest and one of the most difficult hydrologic phenomena to measure.
6. Precipitation at a place can be measured in an open vessel -- the idea is ancient, and records of rainfall extend back nearly two centuries. Variations in the type of rain gauge have been introduced. The three main types are recording rain gauges, for measuring minute-by-minute intensity as well as amount of rainfall;

standard rain gauges, in which the catch is read daily; and seasonal gauges, usually placed in mountainous or remote regions, which store the catch over several-month intervals between readings. National networks must contain all three types of gauges, and the Hydrologic Commission of the World Meteorological Organization is at work to devise principles adaptable to design of such networks.

7. The hydrologic problem, however, is to assess rainfall over an area during short periods of time, as during the development of a flood. In general, the accuracy of an areal assessment is proportional to about the 0.6 power of the number of gauges. This means that the number of gauges must increase faster than accuracy, so that to obtain reliable estimates a rather dense network becomes necessary. And even if such a dense network were attainable, there remains the problem of obtaining current information during the progress of a storm. These are the factors that make accurate measurement of the areal distribution of precipitation difficult.

8. Radar equipment has been developed to meet these hydrologic and associated meteorological needs. ^{1/} Adequate radar equipment used by experienced operators cannot only provide an instantaneous picture of rainfall intensity, but also furnish data for extrapolating a few total-catch gauge measurements into an accurate storm isohyetal map. Furthermore, radar permits estimates of rain intensity and total storm precipitation to be made over terrain where standard rain gauges are impractical.

9. The ability of weather radar to sense rainfall depends on the interaction of high-frequency electromagnetic waves and water drops in the atmosphere. When a high-frequency radio wave impinges on a parcel of air containing water drops, some energy is scattered in all directions by individual drops and some passes through. The net effect of a cloud of particles on a high-frequency radio wave is to reflect some energy and pass some through. The ratio of energy reflected and of energy passing through to the initial energy of the wave depends on frequency of the wave, number of droplets, size of droplets, and size of cloud.

10. The maximum practical range of a radar set is limited by the earth's curvature. Although refraction of the radio waves in the atmosphere bends the transmitted rays slightly below the optical line of sight, the net result is that the center of a radar beam rises to an elevation of 15,000 feet at 160 nautical miles. Thus there is a practical limit to the maximum range of a radar set, because increases in range from increases in transmitter power result in loss of distant echoes from lower elevations.

11. The oscilloscope screens of the U. S. Weather Bureau WSR-57 radar (figure 1) have phosphorescence with persistence that indicates a time-average picture of conditions. The indicator displays may be visualized by considering the signal indications that would come from a hypothetical metal sheet suspended in the sky. Thus, the "P.P.I." scope displays a circular map of echoes centered about the radar set, the "A" scope shows the distance to and intensity of echoes, and the "R.H.I." scope shows a vertical view of the echoes along an azimuth.

12. The radar operator may use either of two methods for recording the areal distribution and intensity of rainfall. He may mark the areal limits of the storm and the isoecho patterns on a transparent sheet placed over the P.P.I. score (overlay method) or he may use a camera to photograph the P.P.I. scope (multiple-exposure method). The record of the storm consists of maps or photos taken at equal intervals during the time the storm is within range of the set.

^{1/} U. S. Weather Bureau: The radar program of the U. S. Weather Bureau, Washington (1961).

Ground Water

13. During the past decade, important emphasis has been given to the development of ground water in the newly emerging nations, particularly those in the arid regions of the world. Optimum utilization of the resource demands adequate appraisal through collection of relevant data by appropriate surveys and the analysis and synthesis of such data, both before and subsequent to development. Ground water, of course, is a phase of the hydrologic cycle, but the investigation of this water involves techniques and methods that may be distinctly different from those appropriate to other phases of the cycle.

14. The techniques employed in ground-water investigations depend in large measure on the relative sophistication, complexity, and scope of the actual or proposed development of a ground-water system. A total evaluation might include surface and subsurface geological, surface and subsurface geophysical, geochemical, hydraulic, and hydrologic studies. However, a simpler ground-water investigation might include only a few selected elements from among these. Good aerial photography and topographic maps are fundamental to all surveys related to ground water. Also, as the rocks are the natural reservoirs in which ground water is stored and the natural conduits through which it circulates, knowledge of the geologic framework of a ground-water system is essential to its understanding.

15. In recent years, geophysical studies have been used to increasing extent in quantitative and semiquantitative evaluations of ground-water systems. Among surface geophysical methods, electrical-resistivity, seismic, aeromagnetic, gravimetric, and sonar surveys are employed with varying degrees of success. Surface electrical-resistivity surveys are used successfully in one-, two-, and even three-layer systems, where marked discontinuities occur in the electrical-resistivity profile and where the thickness of each layer is appreciable in relation to the depth of the depth of the discontinuity. Such surveys are particularly useful in establishing fresh water-salt water interfaces in coastal aquifers. Seismic surveys are used mainly to map discontinuities between impermeable bedrock and overlying water-bearing unconsolidated or semiconsolidated sediments. The method is adequate only where there is a marked contrast in the elastic properties of the two types of rock. Aeromagnetic and gravimetric methods are also used to locate buried bedrock surfaces where appreciable discontinuities in rock magnetism and density exist in two-layer systems. Although these methods are not widely used in ground-water problems in the United States, they have found considerable application in countries of the Eastern Hemisphere. Aeromagnetic methods are particularly useful where rapid reconnaissance delineation of aquifers is required over broad regions. Mapping of bedrock surfaces and thickness of unconsolidated overlying deposits by techniques and equipment using low-frequency sound waves also is finding increasing application, particularly in underwater problems in coastal areas. The principles employed are the same as those used in sonic depth finders.

16. Subsurface or borehole geophysical methods are now widely employed in practically all moderately intensive or detailed ground-water investigations. Electrical logging is perhaps the most useful tool in distinguishing aquifer contacts, formation porosity, water quality, and fresh-salt water interfaces in uncased boreholes. Also this method can be used quantitatively, if other supplementary field data are available. Gamma-ray and neutron logging is also increasingly used for stratigraphic correlation, particularly between cased wells. However, proper interpretation of such radiation logs requires considerable antecedent knowledge of the local lithology. Limestones and dolomites, for example, have radioactive intensities similar to sandstones.

17. The importance of depth-temperature relations in ground-water systems is

increasingly recognized, particularly with respect to water viscosity and the effective permeability of aquifers. An important tool in the analysis of these relations is the temperature log, which utilizes conventional electric logging circuits to measure resistance change of a temperature-sensitive metallic conductor. By this method, which can be used in both cased and uncased wells, a temperature log and a corresponding reciprocal-gradient log are derived. From these logs it is possible to identify the aquifer or aquifers tapped by wells. Borehole diameter or caliper logging is an important tool in long-range stratigraphic or aquifer correlation. The caliper log is also used to determine the condition of an under-reamed section of a borehole prior to placement of a gravel pack and well casing, and to estimate the volume of cement necessary to fill the annular space between the well casing and the borehole wall. This technique is based on variation of borehole diameter which reflects differences in the lithologic character of the rocks penetrated by the drill. Another borehole technique of wide application is flow-meter logging which provides a record of the velocity and direction of movement of water in a well. The log may be made while the well is discharging water at the land surface, while water is being introduced, or while the well is idle. The flow-meter log serves to identify and evaluate the aquifers tapped by cased wells having multiple screens, leaks in cased wells, and permeable zones penetrated by cased wells. Still another borehole technique is fluid-conductivity logging which provides a record of the electrical conductivity of the borehole fluid at all depths. Such a log provides useful information on the position of salt-water leaks in cased artesian wells and the depth and relative artesian head of salt-water aquifers penetrated by cased wells. Still more recently, compact television cameras with wide-angle lenses of short focal length are being designed for on-site inspection of well casings and examination of the lithologic character of borehole surfaces.

18. Perhaps the most sophisticated technique now in use in the laboratory analysis of simulated ground-water systems is the passive-element analogue model which is based on the direct analogy between electric and fluid force fields. (See Figure II.) For any ground-water system, an analogue model employing resistor-capacitor networks with analyzers can be constructed, with a degree of complexity depending on the nature of the ground-water system and the available basic data. In the model, the fundamental aquifer variable (transmissibility) is simulated by an electrical variable (conductance), and aquifer storage is simulated electrically by capacitance. The electric analogue model affords a useful means for computing the distribution of potential (or head) at any point in the system under complex boundary conditions as well as variable recharge and withdrawal by pumping.

19. The chemical characteristics of ground water are very important with respect to its utilization as well as with respect to geochemical methods for analyzing ground-water systems. Identifiable chemical constituents in minute concentration are particularly useful in tracing the direction and velocity of water movement through the rock skeleton but must be used in conjunction with adequate geologic and hydrologic knowledge of the ground-water system. Induced tracers such as salt solutions, fluorescein, and radioactive materials commonly are used for this purpose. Also radioisotopes, such as carbon-14 and tritium, are proving useful in determining the relative age of water in different parts of a ground-water system and the span of the "life cycle" of such a system. Chemical quality and temperature relationships also enter into the quantitative evaluation of other ground-water problems, including salt-fresh water relationships in coastal aquifers, base exchange, influx of mineralized waters or brines, aquifers as heat exchangers, induced infiltration, artificial recharge, and disposal of radioactive wastes.

20. Because of the importance of the transmission and storage characteristics in the hydraulic behaviour of aquifers and ground-water systems, a considerable number of methods have been evolved for the mathematical analysis of problems in fluid

mechanics as they apply to ground-water flow systems. To enumerate, well methods of aquifer evaluation include those involving constant discharge or recharge without vertical leakage, instantaneous discharge or recharge, constant head without vertical leakage, constant discharge with vertical leakage, and variable discharge without vertical leakage. Channel or drain methods include those applicable to constant discharge, constant head, and sinusoidal head fluctuations. Numerical analysis and flow-net analysis provide the chief areal methods of aquifer evaluation. Also, the analysis of hydrologic boundary problems has been built on a number of methods involving the theory of images.

21. Quantitative evaluation of ground-water systems by hydrologic methods has had a considerably longer history of evolution in the United States than the development and use of hydraulic methods. Appraisal of the ground-water resource requires an accounting of the perennial intake, discharge, and changes in storage with relation to man's existing and future needs for ground-water supplies. In addition, water quality must be adequately defined with regard to temporal and spatial changes in ground-water systems and the effects of such changes on man's use of the water. Among the seepage methods for evaluating the recharge-discharge balance in ground-water systems are seepage surveys keyed to streamflow records from gauging stations and analysis of stream hydrographs, the base-flow hydrograph analysis, and water-budget studies. Methods for estimating recharge or discharge from changes in ground-water storage include lysimeter or tank studies, observation-well hydrographs, isopachous maps of net change in water level, saturation or drainage techniques, and indirect methods. In all storage methods, specific yield must be known to convert changes in storage volume to water volume.

Surface Water

22. A most significant development in the collection of hydrologic data in the United States in the past decade has been that of a digital recorder for the measurement of river stages. These instruments punch a digitized record of water level on a paper tape in a manner compatible with systems of computation by high-speed digital computers. The records may be used with any of several stage-sensing devices -- floats, pressure transducers, or gas-purge (bubble gauge) systems of head-pressure sensing.

23. The records-processing program begins with a stage record obtained from a digital-recorder gauge (see Figure III) and ends with a computer print-out listing mean daily discharge rates, computed monthly and annual averages, maximum and minimum rates of flow during monthly and annual periods, and flood-hydrograph data for floods meeting preselected criteria.

24. The entire processing procedure is called a "gauge to page" plan, for almost the entire process is accomplished by the use of machines, the only human factor being the introduction of judgment factors into the programming of computer operations. The print-out from the computer is ready for reproduction by photographic methods for formal publication.

25. The procedure, in brief, begins with a stage-sensing device installed at the gauging site on a river, which activates a digital recorder to punch a digitized record of stage on a paper tape. This record on paper tape is translated by machine to magnetic tape in appropriate computer language. A program is designed for a high-speed computer which takes the magnetic tape, combines it in the computer operations with the programmed commands for stage-discharge relationships and the desired discharge products, and proceeds to perform all commanded operations and print out the results. Using the techniques described, it is now possible to compute a year's record in only a few minutes, whereas the same operations performed

by hand require many hours.

26. A second significant development in the collection of river data in the United States is the invention of a stage-sensing device called a "bubble gauge." This gauge (Figure IV) was developed to record reservoir and river levels without the use of stilling wells and intake pipes, which are often expensive to construct and difficult to maintain. The gauge consists of a specially designed servomanometer, a transistorized control, a gas-purge system, and a recorder. The pressure corresponding to the head of water is brought to the manometer by the gas-purge system. Nitrogen gas is discharged slowly through plastic tubing from the gauge house to an orifice located at a fixed elevation in the stream. The pressure at the orifice, and hence at any point in the delving tube, is related to the head or depth of water over the orifice. This pressure is in turn transferred to the manometer and then to the recording device. The manometers have a sensitivity of ± 0.005 foot, and the entire assemblage can be constructed to record ranges in stage in excess of 120 feet. A differential type of manometer may be adapted to the instrument to record directly the slope in a short reach of river channel.

27. Several new field instruments are undergoing development and field tests in the United States, and will soon significantly influence data-collection techniques. One of these is a velocity meter based on measurement of the electromagnetic effect of flowing water. This meter will generally be adapted to the continuous measurement of water velocity at preselected points. An acoustic velocity meter is being tested, which will measure the mean velocity in a line across a stream channel. The meter is based on the Doppler principle and relates water velocity to the difference in travel time of ultrasonic waves moving in opposite directions between transducers located across the stream from each other and offset from each other in a longitudinal direction. We are also attempting to develop a small portable current meter based on the Doppler principle. The Doppler effect is evident in a change in frequency of an emitted signal due to motion of the water and suspended sediment with respect to the meter. The meter, which gives a direct reading of velocity, appears to be particularly applicable to the measurement of very low stream velocities. The instrument will be fully transistorized and battery-powered, resulting in a light portable device admirably suited to use by field personnel.

28. A special depth-sounding and velocity-measuring device has been developed for measuring extreme flood flows. This instrument combines a fathometer, a direction compass, and a Price current meter, and permits measurements of depth, direction of current, and near-surface velocity with a single setting and without encountering the hazards of complete depth sounding by sounding weight. The technique of augmenting continuous flood records by operation of only crest-stage gauges has been enhanced by the development of a small, cheap (\$50) water-stage recorder. This recorder may be operated intermittently in a 3-inch pipe well to obtain only flood hydrographs.

29. Streamflow data-collection programs in the United States include provision for determinations of suspended sediment and chemical quality of river flow. Water-temperature measurements are a routine part of water-quality observations. As in the collection of flow data, techniques for collection and analysis of water samples have been refined in recent years. Newer methods for chemical analysis of water include such instrumental techniques as spectrophotometry and flame photometry. Increasing emphasis is being given to development of techniques for measuring trace elements. During recent years several models and sizes of depth-integrating samplers have been developed to permit accurate and efficient sampling of sediment suspended in river flow. A depth-integrating sampler is moved vertically through the sampling zone at a constant rate and admits a water-sediment mixture at a velocity about equal to the stream velocity at all points of its travel. Other samplers have been

developed to sample continuously at a point, and to collect bed material for particle-size examination.

30. Much effort is being expended in the United States in the development of techniques of analysis for the generalization and synthesis of streamflow data. It is never possible to collect information at all potential sites of need. The problem usually faced requires generalization of existing data in such manner as to form a basis for the synthesis of flow data at ungauged sites to acceptable limits of accuracy.

31. Perhaps the most difficult problem facing water-data program planners is the design of adequate networks for the collection of field measurements. Intuitive and judgment factors are utilized in beginning such networks. Appropriate weight is given to sampling areas having differing terrains, geology, and climate, and to existing needs for data at specific sites. As techniques are improved, and the needs for data increase, networks are expanded.

32. Several years ago the network of streamflow and water-quality gauging stations in the United States had grown to such proportions that it was necessary to evaluate the entire program. The principal classifications of stations derived from this and subsequent studies follow: (1) primary stations, those having essential hydrologic significance and operated for indefinitely long periods; (2) secondary stations, those at which continuous flow records are obtained for a period of only a few years (5 to 10); and (3) partial-record stations, those at which flows, or stages, are measured only during extremes of either high or low conditions.

33. In testing the existing design of primary gauging stations, statistical methods were used to determine the degree of independence of stations in the network. With these criteria it was possible to eliminate some stations and to pinpoint new areas needing gauging. Thus, the optimum extent of the required primary network was determined.

34. The principal rationale in the use of networks of secondary and partial-record stations is to obtain a maximum amount of data at minimum cost. Modern statistical methods in hydrology permit records from these shorter or less complete operations to be extrapolated to accurate estimates of flow parameters for longer periods. Networks of such stations become more dense as water development proceeds in an area and the need for more detailed hydrologic information increases.

35. A final consideration in the responsibility of a government to furnish hydrologic data for its own use and that of its citizens is the preservation of the data in a place and in a form useful and available to all. Our emphasis in the United States is on data accurate by high technical standards, centrally filed, permanently preserved, and readily available. High consideration is given to the introduction of new techniques where they have promise of adding accuracy or decreasing costs. Much of what has been learned is directly applicable to the newly developing countries.

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NEW STEPS TOWARD BETTER DATA AND INVESTIGATION
FOR WATER RESOURCES DEVELOPMENT

ANNEX I

- Fig. I - Major Components of the WSR-57 radar
- Fig. II - Passive element analogue model showing oscilloscope, input generator, and resistor-capacitor network of San Simon Basin, Arizona.
- Fig. III - Digital Recorder
- Fig. IV - Raubbles Gauge to register river levels



UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

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23 Nov.1962

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C O R R I G E N D U M

The 4 following figures were omitted by error:

(See overleaf)

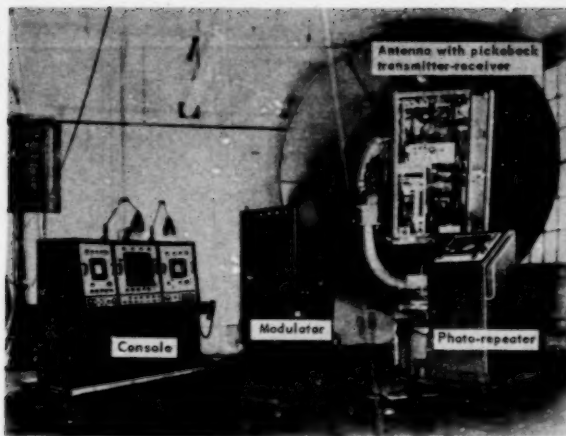


FIG.I Major Components of the WSR-57 radar.

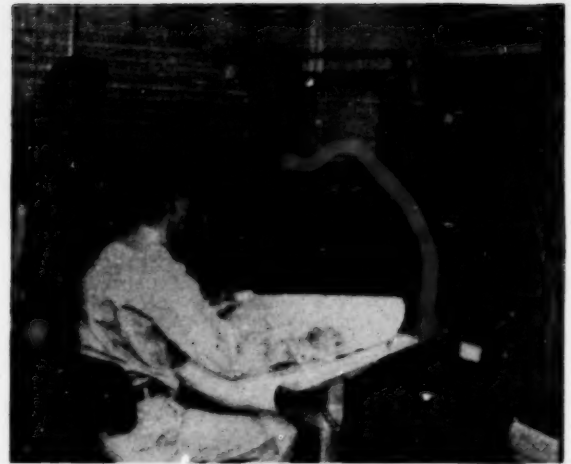


FIG.II Passive element analogue model showing oscilloscope, input generator, and resistor-capacitor network.

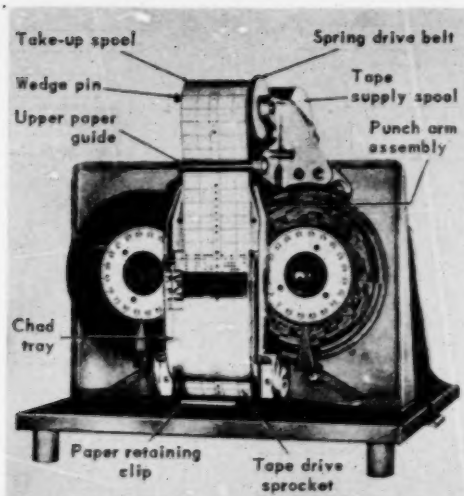


FIG.III Digital Recorder.

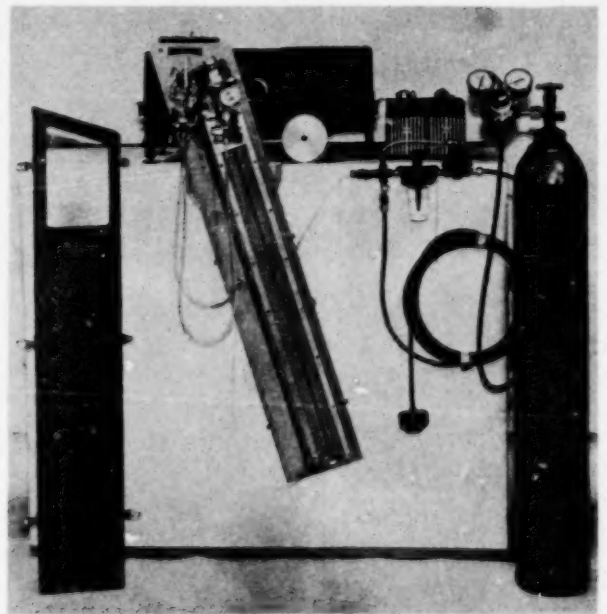


FIG.IV Bubble Gauge to register river levels.



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Agenda Item : A.4.1

United States of America

**TECHNIQUES FOR APPRAISING
THE ENERGY ECONOMY AND OUTLOOK
IN LESS DEVELOPED COUNTRIES**

By Nathaniel B. GUYOL,
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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.
2. Papers selected for inclusion in Specialized Sessions will be available at the Conference in only one of the above official languages.
3. Summaries of all papers, as submitted by contributors, will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.
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TECHNIQUES FOR APPRAISING THE ENERGY
ECONOMY AND OUTLOOK IN LESS DEVELOPED COUNTRIES

by

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1. The purpose of this paper is to outline one approach to energy planning and forecasting and discuss its applicability to the less developed countries of the world.
2. The approach consists mainly of the construction of a complete energy balance for the country under consideration; appraisal of the influence of various physical, economic and institutional factors upon this balance; and application of the understandings thereby gained to the problems of planning and forecasting.
3. The energy balance is a device that has proven particularly useful in the collection and organization of data on the physical aspects of the energy economy. It is in fact nothing more or less than a consolidated account for all sources of energy, in which the several sources used in a particular area during a stipulated period of time are expressed in a common unit and brought together in a single table or graph. Fully developed, the energy balance traces each source of energy from origin to effective use, showing at each stage in this flow the physical and functional interrelationships of the several energy sources.
4. This analytical tool has come into rather wide use during the past decade, but mainly for countries that get most of their energy from sources that enter normal trade channels and are duly recorded - that is, the so-called commercial sources of energy. Among these countries are Austria¹, Belgium², Bulgaria³, Canada⁴, Germany⁵, Italy⁶, the Netherlands⁷, Spain⁸, and the U.S.A.⁹.
5. There is at least one case, however, in which an energy balance has been constructed for a country that depends primarily upon non-commercial sources of energy. This case is India, whose energy balance is shown graphically in Figure I, and statistically in Table 1 appended to this paper¹⁰.
6. The chart and the table demonstrate the importance of non-commercial sources of energy, including even draft animals, in less developed countries. In this particular case, it should be noted that draft cattle provide nearly as much power as all other sources of energy combined, and non-commercial fuels, such as firewood and dung, more heat than all other sources of energy combined.
7. The main point in presenting the chart, however, is to demonstrate that energy balances can be constructed for less developed countries when needed. So far as commercial sources of energy are concerned, it is, in fact, somewhat easier to prepare accounts for less developed than for developed countries. The volumes to be accounted for are smaller; the flow from production or imports to end-use is ordinarily simpler; and the pattern of distribution is usually less diverse.

8. On the other hand, balances for less developed countries are complicated somewhat by the necessity of including non-commercial sources of energy, especially when the work output of draft animals must also be taken into account. This is not as difficult as it may seem, for supply and demand of energy from these sources can be estimated, with accuracy that suffices for most purposes, by methods developed in the Statistical Office of the United Nations¹¹ and the U.S. Department of State¹².

9. The most difficult problem that arises, in both developed and less developed countries, is that of estimating the quantities of energy effectively used - that is, the amount of energy converted to useful heat, light or power. The importance of this calculation cannot be over-emphasized, because the real costs of energy are determined as much by efficiency of use as they are by prices. Diesel oil, for example, is far more expensive per unit of contained energy than is coal, but as a locomotive fuel it costs less than coal per unit of work performed because of the relatively high efficiency with which it is used.

10. Reasonable approximations of effective use, satisfactory for most purposes, can be obtained by the application of standard efficiency factors to data on energy supplied to various consumer groups. The efficiency factors needed can be obtained from any one of a number of studies such as the United Nations paper on World Energy Requirements in 1975 and 2000¹³, and the papers previously referred to in footnotes 2, 6, and 9. Standard factors such as these can sometimes be improved upon, however, by special surveys of combustion practices and results¹⁴.

11. National energy balances such as those described above provide most of the data needed concerning physical aspects of the energy economy, especially where the country dealt with is small. In large countries such as India, these can be usefully supplemented by regional energy accounts, especially when patterns of energy supply and demand vary significantly from one region to another.

12. The usefulness of both national and regional accounts is considerably enhanced when they can be repeated for a series of years, thus affording a basis for computing historical rates of growth in production, consumption, or other phases of supply and demand.

13. For planning purposes, data on energy reserves are needed, especially data on the location of mineral fuel deposits and water power sites that are readily accessible to domestic markets and can be developed at relatively low cost.

14. Energy balances provide a useful panorama of the energy situation. When repeated for a series of years and supplemented by data on energy reserves, they also provide some understanding of why the energy economy operates as it does. For a more complete understanding, it is necessary to consider also certain other factors which affect the energy economy - economic and institutional factors in particular.

15. Costs are among the factors to which particular attention must be given - mainly costs to consumers, but also costs to the economy as a whole and costs to the country in foreign exchange.

16. Data on costs appear to be relatively rare, but a surprising volume of such data can be assembled through systematic research within the area under study. In India, for example, it was found possible to obtain data on the costs of energy to industrial establishments, railways, power systems, households, airlines, gas works, and motor vehicle operators. It was also found possible to obtain data on pithead prices of coal, on prices of petroleum products at refineries and distribution depots, on costs as well as charges for moving coal by rail, on charges for moving fuels by ship, on the aggregate values of fuels imported and exported, and on taxes on petroleum products

and coal. Altogether, enough data were available to reveal the structure of energy costs in each sector of the economy and each major portion of India.

17. Institutional factors that affect the energy economy include the agencies responsible for managing portions of the energy economy; the instruments through which control is exercised, such as price controls, taxes, and subsidies; and the will of the government and the people to develop the national economy.

18. Data on institutional factors are not sought through separate research, but are accumulated in the course of normal research on physical and economic aspects of the energy economy. Some, such as taxes and subsidies, are brought to light through studies of the structure of prices or costs. Others are indicated simply by deviations of the supply-demand pattern from its expected course. As a rule, institutional factors tend to stand out in the publicly operated branches of the energy economy, and to fade into the background under private enterprise.

19. With data on the physical, economic and institutional aspects of the energy economy in hand, an analysis of the energy situation becomes possible. This appraisal can be addressed initially to the single question: are consumers getting the energy they require? If they are not, there is need for immediate action to find out why not and what can be done to see that they get what they need practically regardless of cost. The penalty paid for any energy shortage normally exceeds by far, in terms of production, the costs of energy itself.

20. As a rule, it is fairly easy to find out whether consumers are getting the energy they require. Shortages, when they occur, have rather dramatic consequences, such as the closing down of industrial establishments, rationing, load shedding, and rapidly rising prices. They are therefore likely to be given considerable prominence in the press and other news media.

21. Attention must also be focussed on the costs of energy to consumers, to the economy as a whole, and to the country. Costs to the economy as a whole may be defined as consumer costs adjusted upwards to correct for subsidies and downwards to correct for taxes. Costs to the country may be defined as the net gains or losses in foreign exchange that result from the purchase of energy from foreign sources.

22. It is relative costs that are important to consumers and to the economy as a whole. The real question is one of whether energy is being made available to the two groups at as low a cost as possible, taking into account relative efficiencies of use as well as relative prices of the several energy sources. As previously indicated, the importance of taking efficiencies of use into account cannot be over-emphasized.

23. The appraisals described above will have brought to light many of the problems and opportunities facing the energy economy. They will thereby have created a sound basis for energy planning, the objective of which is to maximize the contribution of energy to the development of less developed areas.

24. A somewhat different approach is needed for forecasting, because forecasting is concerned with things as they are likely to be rather than things as they should be.

25. One basis for forecasting is provided by data on historical trends in demand or supply of energy. The value of such data is extremely limited, however, because of potential changes in the fuels used and in the efficiency with which they are used. As a rule, the main value of trend data is in indicating probable upper and lower limits to the development of supply or demand.

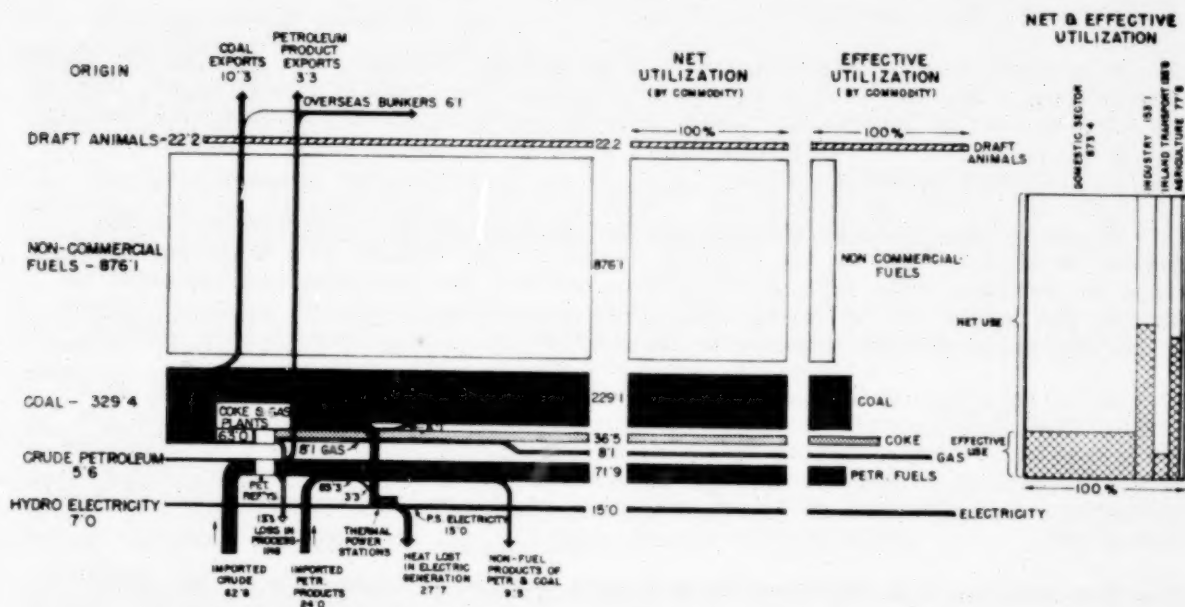
26. Forecasts of national product also provide a basis for estimating future needs and supplies of energy, but only on the basis of the historical relationship of energy to national product. The results obtained by this device are no more satisfactory than simple projections of the energy curves.

27. To get really satisfactory forecasts it is necessary to take into account, in addition to historical trends, various economic and institutional factors that influence energy demand and supply. The real problem is to ascertain how much weight should be given to each of the factors affecting demand or supply. In private enterprise economies, where economic forces have relatively free play, the pendulum is likely to swing toward economic factors. In public enterprise economies, institutional factors are more likely to dominate. But there is no hard and fast rule to guide the forecaster. He must, finally, weigh intuitively that which he cannot weigh mathematically.

FIGURE I

ORIGIN AND UTILIZATION OF ENERGY IN INDIA — 1959

(DATA IN MILLION MEGAWATT HOURS ELECTRICITY EQUIVALENT)



FOOTNOTES

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TABLE I
INDIA'S ENERGY BALANCE, 1952
(In Million MWh Electricity or Equivalent)

	Coal	Coke	Coal Gas	Crude Oil	LPG	Avgas	Je Fuel	Keros	Dist. F/O
Primary Production	329.4	-	-	5.6	-	-	-	-	-
Secondary Production	-	42.5	8.1	-	0.1	-	-	9.5	17.7
Net Import	-9.7	-0.5	-	63.1	-	1.1	1.8	14.7	2.8
Gross Consumption	319.7	-0.5	-	68.7	-	1.1	1.8	14.7	2.8
Overseas Bunkers	1.0	-	-	-	-	0.3	0.3	-	0.3
Gross Inland Consumption	318.7	-0.5	-	68.7	-	0.8	1.5	14.7	2.5
Processed in									
Coke Ovens	43.3	-	-	-	-	-	-	-	-
Gas Works	1.3	-	-	-	-	-	-	-	-
Soft Coke Works	18.7	-	-	-	-	-	-	-	-
Petr. Refineries	-	-	-	68.7	-	-	-	-	1.3
P.S. Elect. works	32.2	-	-	-	-	-	-	-	1.3
Total	95.5	-	-	68.7	-	-	-	-	1.3
Net Inland Consumption(1)	229.1	(2) 36.5	8.1	-	0.1	0.8	1.5	24.2	18.9
Utilisation (Input)									
Transportation	108.8	-	-	-	-	0.8	1.5	10.4	13.3
Industry	95.3	21.9	7.8	-	-	-	-	-	2.9
Domestic Sector	4.8	13.1	0.3	-	0.1	-	-	23.7	-
Agriculture	6.4	-	-	-	-	-	-	0.5	2.7
Non-fuel	-	1.4	-	-	-	-	-	-	-
Lost & Not Acct'd	13.8	0.1	-	-	-	-	-	-	-
Total	229.1	36.5	8.1	-	0.1	0.8	1.5	24.2	(3) 20.2
Utilisation (Output)									
Transportation	6.8	-	-	-	-	0.1	0.2	1.0	0.8
Industry	52.4	12.0	6.2	-	-	-	-	-	0.9
Domestic Sector	1.4	3.9	0.2	-	0.1	-	-	1.6	-
Agriculture	2.5	-	-	-	-	-	-	0.1	0.5
Total	63.1	15.9	6.4	-	0.1	0.1	6.2	1.7	3.2
Heat	58.0	15.9	6.4	-	0.1	-	-	1.2	-
Power & Light	5.1	-	-	-	0.1	-	0.2	0.5	3.2

TABLE I (Continuation)

	Resid P/O	Ref. Fuel Loss	Non-fuel Products	P.S. Elect	All comm. Sources	Non-comm. Fuels	Inanimate Sources	Draft Power	All Sources
Primary Production	-	-	-	7.0	342.0	876.1	1,218.1	22.2	1,240.3
Secondary Production	19.9	4.0	4.3	8.0	126.3	-	126.3	-	126.3
Net Import	-1.5	-	3.7	-	73.7	-	73.7	-	73.7
Gross Consumption	-1.5	-	3.7	7.0	415.7	876.1	1,291.3	22.2	1,314.0
Overseas Bunkers	4.3	-	-	-	6.2	-	6.2	-	6.2
Gross Inland Consumption	-5.8	-	3.7	7.0	409.5	876.1	1,285.6	22.2	1,307.8
Processed In									
Coke Ovens	-	-	-	-	43.3	-	43.3	-	43.3
Gas Works	-	-	-	-	1.3	-	1.3	-	1.3
Soft Coke Works	-	-	-	-	18.7	-	18.7	-	18.7
Petr. Refineries	-	-	-	-	68.7	-	68.7	-	68.7
P.S. Elect. Works	2.1	-	-	-	35.6	-	35.6	-	35.6
Total	2.1	-	-	-	167.6	-	167.6	-	167.6
Net Inland Consumption	12.0	4.0	8.0	15.0	368.7	876.1	1,244.8	22.2	1,267.0
Utilisation (Input)									
Transportation	0.8	-	-	0.5	136.1	-	136.1	1.0	137.1
Industry	10.7	4.0	-	9.0	151.6	1.5	153.1	-	153.1
Domestic Sector	-	-	-	2.7	44.7	828.7	873.4	-	873.4
Agriculture	0.6	-	-	0.7	109	45.9	56.8	21.2	78.0
Non-Fuel	-	-	8.0	-	9.4	-	9.4	-	9.4
Lost & Not Acct'd	-	-	-	2.1	16.0	-	16.0	-	16.0
Total	(4) 14.1	4.0	8.0	15.0 (5)	372.0	876.1	1,244.8	22.2	1,270.3 (5)
Utilisation (Output)									
Transportation	1.0	-	-	0.5	11.4	-	11.4	1.0	12.4
Industry	6.4	2.4	-	-2.0	78.3	0.6	78.9	-	78.9
Domestic Sector	-	-	-	1.4	8.6	124.3	132.9	-	132.9
Agriculture	0.3	-	-	0.7	4.1	13.8	17.9	21.2	39.1
Total	7.7	2.4	-	0.6	102.4	138.7	241.1	22.2	263.3
Heat & Light	6.7	2.4	-	13.8	76.9	138.7	215.6	-	215.6
Power & Light	1.0	-	-	14.4	25.5	-	25.5	22.2	47.7
(1) Including 5.6 from oven coke and 0.4 accounting difference (2) Excluding 6.3 transferred to coal/soft coke; including 0.7 transferred from oven coke (3) Including 1.3 converted to electricity (4) Including 2.0 converted to electricity (5) Including 3.3 converted to electricity									
					LPG-Liquefied Petroleum Gas Kerosene Motor Gasoline Dist. P/O-Distillate Fuel Oil Ref. Fuel-Loss-Refinery Fuel & Loss All Comm. Sources-All Commer- cial Sources				
					Avgas-Aviation Gasoline Kero-Kerosene Resid. P/O-Residual Fuel Oil P.S. Elect.-Public Supply Electricity Non-Comm. Fuels-Non Com- mercial Fuels				

Source: National Council of Applied Economic Research

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NUCLEAR AND CONVENTIONAL ELECTRIC ENERGY IN BRAZIL

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NUCLEAR AND CONVENTIONAL ELECTRIC ENERGY IN BRAZIL

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1. INTRODUCTION

As in most countries today there is a steady demand for electric energy in Brazil. This problem is especially important in this country and other less developed areas as the growth in installed capacity and production should not only satisfy normal necessities of economic development but also cover an increase in "per capita" consumption which is now very small. Thus, during the last 10 years the production of electric energy increased at a rate of approximately 10% per year. The "per capita" capacity increased from 38,2 watts in 1952 to 55 in 1958 and to about 73 in mid 1962. At the moment there is no indication of decrease in this rate of growth. In fact, in some regions this increase is much faster.

Under these conditions and disregarding possible local variations it can be said that by 1969 some additional 5,000,000 kW should be installed in Brazil (5,162,212 kW being the installed capacity on May 30, 1962).

The question arises as how to best fulfill this task from the standpoint of the nature of power plants to be installed. In particular it is desirable to know whether construction of nuclear plants might speed up or in any other way help to attain the objective.

It is the purpose of this work to study this problem in the hope, that it might help to answer some of these questions.

2. OUTLINE OF BRAZILIAN ELECTRIC POWER SITUATION

a) South Central Region

The South Central Region comprises the States of Minas Gerais, São Paulo, Rio de Janeiro, Guanabara, Espírito Santo and part of Paraná. In it are concentrated the most important economic and cultural activities of Brazil. Its area is approximately 1,000,000 sq. km., and its population about 32,000,000.

Up to now, the most complete study of the South Central Region electric power situation has been made (finished in December 1961) under the auspices of Central Elétrica de Furnas S.A. by a consulting firm.

Its results are condensed in fig. I. The installed capacity is, at present, about 3,600 MW. In fig. I are indicated the power plants under construction or already studied with estimated dates of beginning of operations of their several stages. As can be seen from comparison with the expected demand a deficit of installed capacity is expected, by 1968. Furthermore an even worse deficit in firm energy is to be expected by 1967. (The generation of hydro-plants for this case has been estimated on the basis of the critical period of a hydrological cycle equal to the second driest one in the region - 1943/1945).

In fig. I projects of Urubupunga with a first stage of 1258 MW now under construction and a second stage of 1440 MW and Estreito, already under studies by Furnas and with an installed capacity of 800 MW were not included.

It may be seen, nevertheless, that even with these plants, there still will be a deficit, by 1967-68, both in peak capacity and in firm energy, this last one being especially acute, in view of the plant factor of the hydro plants being around 50 or 60%.

From the foregoing it is seen that the plants now under construction or in an advanced stage of planning will not be sufficient to cover the power deficit foreseen in 1967 for the South Central Region of Brazil.

In order to be able to cover this deficit, a plant of about 500 MW capacity must be planned, designed and built in a period of four to five years. It should be noted, furthermore, that 250 MW are needed as soon as the construction is completed. It is also seen that the plant factor of this power plant will be very high, though depending on the hydrological conditions. In the critical period considered it should be almost 100%. Owing to the relatively low plant factors of existing hydro plants it may be assumed that the plant factor of the new plant might be around 65-70%. As a matter of fact one of the recommendations of the above mentioned study is that in future, more high plant factor power plants should be installed in the South Central Region.

How can the installation of this additional capacity be best achieved?

Large hydro plants such as Três Marias (520 MW) and Furnas (1200 MW) take from 6 to 8 years to design and build.

In the South Central Region there are several sites for hydro plants with capacities equal to or higher than 500 MW. Some of them are already reasonably studied. As an example we can mention the Caraguatatubas project on the Paraíba river in the State of São Paulo, with 500 MW capacity and a plant factor of about 50% and Marimbondo project on the Grande ri-

ver in the State of Minas Gerais, with 600 MW capacity and a plant factor of about 60% due to regularization of the river by upstream projects.

It is believed that, from the technical point of view, if a concentrated effort is begun now, the Caragatatubas project might start operation around 1968-69 and Marimbondo around 1969. This latter one would be built almost simultaneously with Estreito project.

It is seen, then, that it would be rather difficult to build a hydro-plant in time to cover the deficit. The energy production of each of the plants would be also too small, unless the two plants were built at the same time.

In the South Central Region there are more sites that were reasonably studied and probably, many more that were not studied at all. Especially on the Grande River many sites were studied with a total installed capacity of 7000 MW, Estreito and Marimbondo being representative of the larger ones. Nevertheless, it seems that it will be very difficult to build one or more hydro plants in time to cover the deficit foreseen in the region, starting with 1967. All the same, it is important that these sites be fully developed and construction started as soon as possible, in order to be able to keep up with the ever growing demand of the region. These plants, even though not best suited to cover the immediate need because of the time factor involved are necessary to supply part of the demand beyond 1970, being also very economic - cheap to build, located close to load centers and regulated by Furnas, thus being able to work at high plant factors.

Thus, it seems that even though the South Central Region is very well endowed with hydro resources (+), it might be necessary to build a thermal plant in order to have it ready by 1967.

A thermal plant of 500 MW capacity could be built in four years and thus be ready just in time.

The building of thermal plants in Brazil, especially of this size, is not very popular because of the lack of fuel, which has to be imported in great part, and because of great abundance of hydro potential. The usual way to operate a thermal plant would be with a low plant factor, to complement hydro generation and save as much fuel as possible. Nevertheless, under conditions of growth found in the South Central Region, this kind of operation is not always feasible and the only big thermal plant in Brazil (Piratininga with 450 MW, located in the State of São Paulo), operates on base load. As stated earlier it is reasonable to assume that the average plant factor would be about 65%, being higher at the beginning, especially if a critical period occurs. In normal hydrologic years the factor would be lower and some fuel might be saved.

Once admitted the construction of a thermal plant there immediately occurs the question of it being a nuclear plant.

Such a plant could be built in about five years and thus, though later than a conventional thermal plant, it might start its operation earlier than a hydro-plant. This last fact is not very certain because, while the technique of building hydro plants is quite well developed in Brazil, this, of course, is not the case as far as construction of nuclear plants is con-

(+) About 20,000,000 kW of hydro.

cerned. In fact, construction of a nuclear plant of this size constitutes a major engineering problem anywhere in the world. Nevertheless, with the help of entities abroad which have already faced this kind of problem, it might be assumed that a nuclear plant would be built somewhat earlier than a hydro plant. A discussion of economic factors is made in paragraphs 3 and 4.

Here, I would like to point out that there exists, in Brazil a notorious shortage of fossil fuels and thus, if at all feasible, it is highly desirable to save them for applications where they cannot be substituted. On the other hand, the electric power situation, outlined here will, if anything, grow more acute and in the decade 1970 - 1980 about 1000 MW per year should be installed in the South Central Region of Brazil. In order not to disperse the scarce capital and human resources it would be highly desirable to build in the region big plants of at least 500 MW. In this way, many of the hydro sites in the range of 100-200 MW even though feasible from other points of view, will be not worth while to develop owing to the time invol-

ved out of proportion to their size (+). For this reason as well as because of economies in capital investment, larger and more remote sites will be developed, and more big thermal plants, close to the load centers will have to be built. A proportion of these plants will probably be nuclear.

b) Northeastern Region

The Northeastern Region is a vast region of about 1,500,000 sq. km. with a population of 22,000,000. The power problem in this region is rather acute, but the solution is not easy because of very low load concentration.

The Federal Government is promoting the construction of several dams for water storage all over the area. These dams are also utilized to produce power. Several steam and diesel plants have also been installed in the region.

The Federal Government through the "Companhia Hidroelétrica do São Francisco", CHESF, is building the Paulo Afonso hydro plant. This plant will have an ultimate capacity of 1,530,000 kW. The present capacity is 330 MW and the firm capacity is estimated at about 900 MW. In this latter estimate is included the regulating capacity of Três Marias dam recently completed and located on the upper São Francisco in the State of Minas Gerais.

In fig. II, the demand forecast for the region and the steps of expansion of Paulo Afonso plant are shown. The load foreseen for city of Fortaleza, capital of Ceará, 700 km from Paulo Afonso is included in the forecast. On the other hand, the two northernmost States of the region - Piauí and Maranhão - are not included, but their effect on the total is rather small.

- (+) This does not apply to many sites of this size, located downstream from big reservoirs such as Três Marias and Furnas. Plants built in these sites will have water regulated by these reservoirs and will be able to work at high plant factors, thus producing large quantities of firm energy

It is seen that the Paulo Afonso plant will be able to supply the demand up to 1970, even if the present fast rate of growth is maintained. After Paulo Afonso is completed, at least two other hydro plants can be built in the same region - Itaparica and Curitiba with a total of, approximately, 3,500 MW. Thus, it is apparent, that there is no problem as far as generation is concerned. On the other hand, the problem that might arise, both technical and economical, would be concerned with transmission of this power to the load centers.

Nevertheless, as will be seen later on, the characteristics of Paulo Afonso - low dam, high head and large installed and firm capacities - are such that its power unit cost is exceptionally low. This means that relatively more may be spent on transmission. As far as technical problems are concerned, they are not difficult to solve. As a matter of fact, a 700 km transmission line does not present, nowadays, any special problem, except of course, higher investment costs.

It is desirable, on the other hand, that some local generation be installed at the extremities of these long transmission lines and in other points of the area in order to ensure better reliability, better voltage control and better overall operation: This local generation will be obtained from the small power plants both hydro, installed at the water storage dams, and thermal, as mentioned above.

From this picture it is seen that there is no place for installation of medium and large thermal power plants in the region. This is so because there is no load concentration large enough that might justify the installation of a plant of 100 MW or more and which would not need relatively long transmission lines. Only such a plant might compete with Paulo Afonso, even with its high transmission costs. This is especially true of nuclear power plants.

The only exception might be the city of Fortaleza, where a 100MW plant could be installed.

We shall see, later on, the economic aspects involved in this last case. At present, it can be said that because of low load densities and because of exceptionally low cost of Paulo Afonso plant, nuclear power could not bring much help to the electrification of the Northeastern Region of Brazil.

c) Southern Region

This region comprises part of the state of Paraná and the States of Santa Catarina and Rio Grande do Sul. It has an area of approximately 500,000 sq. km. and a population of 11,000,000. It has a reasonable amount of hydre potential as well as some coal deposits, mainly in Santa Catarina and Rio Grande do Sul. An interesting feature of these deposits is that it is difficult to increase the production of the high grade metallurgical coal because there is not enough demand for the low grade steam coal that is left as by product.

Each of the three States of the Region has its own plan of electrification. The rate of growth of the load is comparable to that of the South Central Region but the capacities involved are much smaller. The greatest blocks of power are needed in Rio Grande do Sul, the biggest and

most developed of the three States. See fig. III for the foreseen demand and plants scheduled for construction through the Electrification Plan of the Rio Grande Electric Energy Commission. It is seen that the demand can be supplied without difficulties by these plants.

Santa Catarina is a small State and its power requirements can be readily supplied by small hydro and thermal plants already installed or under construction.

Paraná has at present about 150 MW of installed capacity mostly small hydro and thermal plants and interconnections with the States of São Paulo and Santa Catarina. The State Government has scheduled to install small and medium hydro and thermal plants with a total capacity of about 500 MW, by 1970. In this capacity is included part of Chavantes hydro plant being built in São Paulo. These plants should adequately cover the foreseen demand.

The supply of electric energy in the Southern Region is thus assured until 1970 if the plans are fulfilled. Nevertheless, questions arise as to the feasibility of giving greater emphasis to construction of thermal plants in view of the coal deposits located at convenient distances, as well as to possibilities of nuclear power. We shall review some of these problems in the next paragraphs.

3. ECONOMIC CONSIDERATIONS

a) General

In this paragraph some costs of electric energy in Brazil have been estimated. For these estimates, a plant of 100 MW and another of 500 MW have been chosen these being the capacities that might be most readily employed in the regions of Brazil studied in the preceding chapter.

The costs per installed kW of nuclear plants have been based on Reference 1, other technical literature and contacts with manufacturers. The cost for conventional thermal plants was obtained from latest surveys in technical magazines. In both cases, adjustments have been made to take into account the change of conditions from countries where the published prices apply and Brazil. For this purpose, the estimated costs of engineering, land and civil works have been deducted from the total price, after which shipping and import expenses and the cost of land and civil works in Brazil and engineering previously deducted have been added and the total price has been obtained.

The estimates for nuclear power have been reasonably close to other estimates made in Brazil. For the conventional thermal power, the estimates check quite well with costs calculated for existing projects.

As for hydro plants, the costs have been estimated with basis on several projects already built, under construction, and planned, with information on costs both published and private, obtained from the entities involved.

All costs have been reduced to conditions at beginning of 1962 and the Brazilian currency cruzeiro has been converted at a rate of US\$.... 1,00 = C 300,00.

The annual plant factors assumed for 100 MW plants are 50% and for 500 MW 65%. The 100 MW plant is supposed to operate in a smaller system,

or completely isolated.

b) Cost of Nuclear Energy

Both natural uranium, graphite moderated CO₂ cooled and enriched uranium Boiling Water Reactor type, nuclear plants have been considered.

For natural uranium cycle, the following assumptions have been made:

Cost of nat. uranium	US\$ 23.5/kg
Fabrication	US\$ 16.0/kg
Shipping	<u>US\$ 18.0/kg</u>
Total	US\$ 57.5/kg

The cost per kwhr assumes cost of 1.5 cores. The burn-up assumed is of 3000 MWD/t, efficiency of plant 30%.

For enriched uranium a 2% enriched fuel is assumed:

Initial value (2%)	US\$146.50/kg
Final value (1%)	- US\$ 47.70/kg
Plutonium credit (0.5%)	
US\$ 9.5/kg	- US\$ 47.50/kg
Fabrication	US\$ 92.00/kg
Shipping	US\$ 18.00/kg
Reprocessing	<u>US\$ 33.10/kg</u>
Total	US\$194.40/kg

Again the cost of 1.5 cores was assumed for the calculation of cost per kWh. Use charge of 4.75% has been applied and a fuel cycle of 5 years, burn-up of 13,000 MWD/t and efficiency of 30% have been assumed.

c) Cost of conventional thermal energy

For estimate of fuel costs, three locations have been assumed: a location close to the seaside, a location in interior of Rio Grande do Sul and a location in interior of Santa Catarina, close to coal mines in both cases.

At seaside, oil has been assumed as fuel, coal being the fuel at interior locations. Prices of oil and coal have been furnished, respectively, by "Conselho Nacional do Petróleo" and "Comissão do Plano do Carvão Nacional". Price of oil is \$ 1.2 per 1000 kcal and of coal \$ 1.00 at the mine in Rio Grande do Sul and \$ 0.50 at the mine in Santa Catarina.

Heat rate of 100 MW plant is assumed as 2,625 kcal (10,500 BTU)/net kwhr and that of 500 MW plant as 2,375 kcal (9,500 BTU) net kwhr.

The plant in Rio Grande do Sul has been assumed more expensive than either the plant in Santa Catarina or the oil fueled plant, because of poor quality of coal in this State.

For heat values of fuel were taken 10,200 kcal per kg of oil, 2,600 kcal/kg of coal in Rio Grande do Sul and 6,090 kcal/kg for coal in Santa Catarina.

d) Other Expenses

Among other expenses, the most important is the cost of money. This is very difficult to establish in Brazil, because of the problems caused by inflation. The official regulations state that the return on capital in electric utilities must not be higher than 10% of the capital invested uncorrected for inflation. On the other hand, more than 20% can be obtained in many other investments but, of course, this high rate is partly accounted for as a means of protection against inflation. Nevertheless, supply of capital is rather scarce in Brazil and this should be reflected in higher interest rates. For this reason, the costs of kWhr have been calculated for what might be considered the two extremes: 10% and 20% of interest.

Depreciation is calculated for a life of 25 years for nuclear plants, 30 years for conventional steam plants and 40 years for hydro plants. The sinking fund method is used. Taxes are very low (about 0.1% of capital cost), as Government owned utilities are assumed in this study.

4. DISCUSSION OF THE RESULTS

a) General

In Table I. are condensed the results of cost studies. From them, the following conclusion is immediately apparent: hydro plants produce power incomparably cheaper than other kinds of plants. Next to it, the power produced by coal fueled plants in Santa Catarina is the cheapest. In fact, this is the only kind of thermal plant that might be compared with hydro in Brazil.

Nuclear power seems to be competitive with conventional thermal power. Power from BWR is less expensive than power from the Natural Uranium reactor.

As far as our study is concerned, the following conclusions can be drawn:

b) South Central Region

A 500 MW nuclear plant, installed in this region would be competitive with a 500 MW conventional thermal plant. An enriched uranium plant produces power considerably cheaper than the conventional thermal plant, for both values of rate of interest assumed. Power produced by Natural Uranium Reactor is very slightly more expensive than that produced by conventional plant for interest rate of 10% and is considerably more expensive for a rate of 20%.

These figures, being estimates, are necessarily approximate but it seems that the conclusion can be drawn that nuclear plants, especially of the Enriched Uranium type, certainly are competitive from an economic point of view, with conventional thermal plants in the South Central Region. This means that, whenever the installation of a thermal plant is envisaged, consideration should be given to a nuclear plant.

Nevertheless, it is seen that thermal plants, both conventional and nuclear produce much more expensive power than the hydro plants and thus should be built only for reasons sufficiently strong to overrule the stric-

tly economic considerations. In the particular case of the 500 MW nuclear plant the possible reasons for its construction - economy in time - might not be decisive because at present it is not yet clear whether a plant of this size could be ordered, designed, shipped and installed in a time much shorter than that required for a hydro plant.

Thus, taking into account the abundance of hydro reserves in the South Central Region, it would seem more advisable to concentrate on hydro plants, with every effort to build them in time and, if necessary, supplement them with medium size conventional thermal plants, which might be built faster and once in operation, might constitute a certain reserve in the system, economising fuel, when sufficient hydro is installed.

c) Northeastern Region

As it can be seen from Table I, Paulo Afonso plant produces extremely cheap power and no other plant, thermal or hydro, produces power at this cost. Thus, it is quite clear that this power should be used before other kinds of plant be considered.

Rough calculations indicate that even the relatively uneconomic 700 km transmission line from Paulo Afonso to Fortaleza, transmitting 100MW at 50% load factor, would increase the cost of power to 10.40 mills/kWh for interest rate of 10% and to 21.00 mills/kWh for the rate of 20% which is still cheaper than comparable amount of power produced by thermal plants.

d) Southern Region

In this region, a 100 MW nuclear plant might be installed in substitution of some of the plants already scheduled for installation. Nevertheless, even in this region of relatively high cost hydro (due to small sizes of available sites), hydro power is cheaper. Nuclear power is slightly more expensive than conventional thermal power installed at mine mouth in Rio Grande do Sul.

Special consideration should be given to coal fired plants in Santa Catarina where higher grade coal mines exist and where the power produced in this way is very cheap. It is interesting to note that even with a 250 km transmission line delivering 100 MW at 50% load factor from Capivari mines in Santa Catarina to Porto Alegre in Rio Grande do Sul, the power would be delivered at about 13.0 and 19.3 mills for 10% and 20% interest respectively, which still is cheaper than other thermal power both conventional and nuclear and is almost competitive with hydro.

This means that Santa Catarina might be an exporter of electric power to the neighbouring States, if economic hydro sites become scarce in the region.

5. GENERAL CONCLUSIONS

We have thus seen that the only region in Brazil, where nuclear power might have some use, at this time, is the South Central Region. Nevertheless, both conventional thermal and nuclear plants produce power so much more expensive than hydro, that every effort must be made, at present, to solve the electric energy problems by means of hydro plants. (A small amount of thermal power might be required to improve system reliability).

An exception to this situation is Santa Catarina, where coal fired plants may produce reasonably cheap power.

It is the author's opinion that, in order to improve the electric power situation in Brazil, making the best use of available science and technology, the following program should be carried out (especially important for the South Central Region):

i) A thorough study of Brazil's real availabilities of hydro potential be made especially as far as the building of big plants (500 MW and up) is concerned.

ii) A complete interconnection of existing systems should be made in order to utilize in the most economic manner the existing generating capacity and in order to be able to utilize most conveniently the power generated by the big plants to be built.

iii) A study of the most efficient and uniform construction methods should be made, as well as standardization of design of hydro plants, in order to decrease the time and effort necessary to build them.

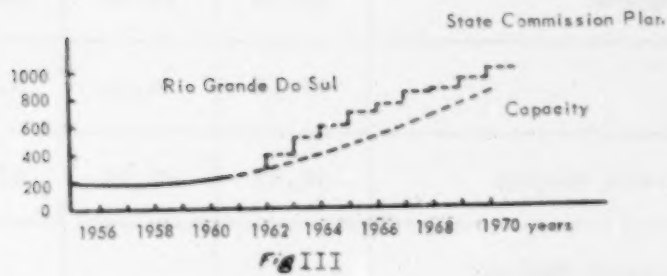
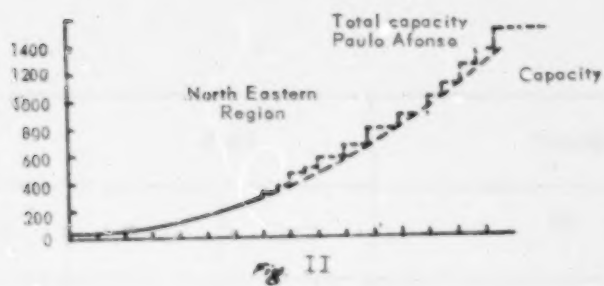
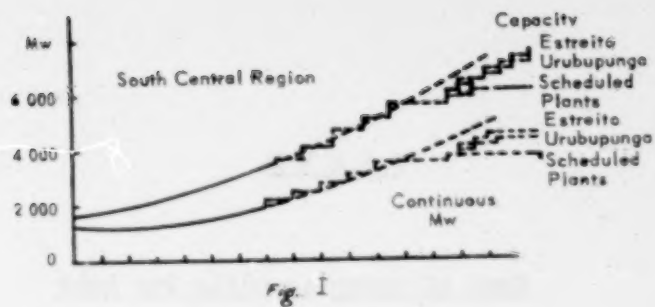
iv) A vigorous effort should be made to solve the Brazilian fuel situation both oil and coal. (First steps were already taken in this direction and Brazil is now producing about 32% of its oil consumption).

v) The nuclear program already under way should be continued and expanded in order to have sufficient manpower and scientific and technological knowledge necessary to choose, order, and supervise the building at first, and later on to design and build power reactors. All efforts should be made to select the most appropriate reactors for Brazilian conditions and to use as much as possible domestic technology and materials. In particular, an intensive program of prospection for uranium and other nuclear fuel ores should be carried on.

vi) The capacity of Brazilian heavy electric industry should be expanded in order to be able to manufacture in Brazil the big generators and turbines that will be necessary (Brazilian industry can already produce large hydro generators. Nevertheless, it will be necessary to produce large water wheels, steam turbines, and turbogenerators). Local industry should also be able to manufacture greater part of other components of thermal plants, both conventional and nuclear.

REFERENCES

- 1) Costs of Nuclear Power - United States Atomic Energy Commission, January 1961



T A B L E

Cost of power in mills per kwhr

INTEREST	10 %		20 %	
	100	500	100	500
Capacity - MW				
Nat. Uranium	21.13	13.55	36.77	22.57
BHEL	17.15	8.63	29.32	13.37
Thermal-oil fueled	16.73	13.26	22.10	16.38
Thermal-coal fueled				
a) Rio Grande do Sul	15.23	11.87	20.80	15.15
b) Santa Catarina	10.85	7.91	16.42	11.19
Hydro-South Central Reg.	8.62	5.50	18.20	11.49
Paulo Afonso - 900 MW	5.66		11.72	

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UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A

United States of America

RESOURCE DEVELOPMENT AND TECHNOLOGY

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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RESOURCE DEVELOPMENT AND TECHNOLOGY

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1. The population density of human beings on earth has now reached the point where industrialization is essential if people the world over are to lead reasonably healthy lives. The task of increasing food production alone requires the manufacture of large quantities of fertilizers, which in turn requires the fixation of nitrogen and the chemical processing of phosphate rock on a large scale. The processing must take place using equipment which requires for its fabrication steel and other metals. The fertilizers must be transported by trains and trucks, along railroads and highways which must be built.
2. The task of increasing food production also requires the manufacture and distribution of pesticides, the extension of areas of cultivated lands and the elaboration of water distribution systems. All of this requires machinery, factories, piping, pumps, chemicals and energy, which are products of an industrial society.
3. Thus, when we consider only the requirements for substantially increasing food production, we must conclude that an appreciable measure of industrialization is necessary. When we add to this the additional requirements for medical facilities and supplies, schools, adequate housing, clothing, communication and transportation, it is clear that a really substantial degree of industrialization is necessary in most areas if people are to lead healthy lives.
4. There are many quantities which can be used to indicate the degree of industrialization of a nation. Particularly useful indicators are the per-capita quantities of steel in use and the per capita annual rates of energy consumption. In industrialized societies, the per capita quantities of steel in use varies from about one ton to about ten tons per person. Per capita energy consumption varies from the expenditure of about one ton of coal (or its equivalent in some other form of energy) per person each year, to the expenditure of about ten tons of coal per person each year. In societies which are predominantly agricultural, the quantities are much lower.
5. The quantity of steel in use (or its equivalent in other substances) which is necessary to support an individual in an industrialized society is itself destined to increase with time. One important reason for this is that, as the pressures upon resources increase, greater technological effort must be placed upon the extraction of needed metals and other materials from substances of steadily lower grade. Thus, since the beginning of this century, the average concentration of copper in processed ores has decreased from several percent to about 0.5 percent. For a given quantity of copper, it is now necessary to handle much more material and to engage in much more technological processing than was necessary sixty years ago. This necessitates the use of more equipment and of greater quantities of chemicals. As a result, the quantities of steel and other metals in use increase.

6. No matter where we turn in the area of raw materials availability, we usually encounter a similar situation. Grades of metallic ores of a variety of types are decreasing. Other essential substances, water for example, are often difficult to obtain easily in adequate quantities. As a result one must dig more deeply, use more complicated processes, and transport larger quantities over greater distances. Again, this requires the use of more equipment, more materials, more steel and other metals.

7. A world population of three billion (3×10^9) persons, if industrialized, would require somewhere between 3×10^9 and 30×10^9 tons of steel in use, were its inhabitants to be provided adequately with the necessities of life and were the steel distributed evenly about the world in proportion to population. Considering the fact that many industrialized areas of the world already have considerably more than one ton of steel in use per person, and considering further the fact that the population of the world is destined to become considerably larger than it is at present, the quantity of steel eventually in use in the world is probably destined to exceed 30×10^9 tons by a considerable amount. Already the use of steel in the United States alone is approaching 2×10^9 tons. It is extremely dubious that the population of the world will stabilize at a level much less than 7×10^9 persons. Under the circumstances it is quite conceivable that the quantity of steel in use in the world may grow in the distant but foreseeable future to something of the order of 70×10^9 tons.

8. Associated with this steel in use, in the form of machinery and structures of various types, there would be vast quantities of other metals. For every ton of steel in use we must utilize about 40 pounds of copper and only somewhat smaller quantities of other metals such as lead and zinc. Thus, were 60×10^9 tons of steel actually in use, about 1×10^9 tons of copper (or its equivalent in some other type of metal) would be required as well. To this must be added the requirements for other metals.

9. In order to power an industrial society, energy equivalent to that contained in about one ton of coal is required each year for every ton of steel in use. Thus, it is quite conceivable that annual energy demands in the world may in the foreseeable future grow to the equivalent of the burning of about 60×10^9 tons of coal annually - about 30 times the present annual rate of consumption.

10. These large long-range estimates of needs for raw materials are cited primarily to illustrate that demands for raw materials in the future will almost certainly dwarf those of the present. As we approach the time when such demands are realities, we will find that supplies of high grade resources are increasingly difficult to locate - that we will be called upon to utilize resources of continually lower grade, to make use of substitute materials, and, with proper application of technology, to minimize the waste of precious substances.

11. At the present time world demands for raw materials are already increasing rapidly. Demands for minerals and metals, which more than doubled between the 1930's and the 1950's, are likely to double again by the 1970's. In Europe alone, the consumption of copper appears destined by 1970 to be double the 1955 rate. When we couple these increases with those taking place in the U.S.S.R. and Japan and in such areas as India and China, it is clear that we are on an exponentially increasing curve of demand. In view of these rapidly increasing demands for essential materials, it is likely that the grades of the sources of these materials are destined to decrease even more rapidly in the future than they have in the past.

12. It is important that we recognize these changes which confront us. At the same time, it is important that we recognize that our technological capabilities can, given

proper effort, enable us to keep pace with the demand. The technological developments which are needed in the years ahead, if we are to be supplied with adequate quantities of raw materials, fall into four broad categories:

(a) The development of improved techniques for locating and assessing the extent of deposits of high, intermediate and low grades both near the surface and at depth.

(b) The development of techniques for lessening and for recycling wastes which have long been tolerated in many countries already industrialized.

(c) The development of substitutes for materials which are in short supply.

(d) The development of improved techniques for utilizing low-grade ores.

13. In principle, there is no lower limit to the grade of ore which can be processed, provided two criteria are fulfilled. First, a satisfactory process must be developed by the scientists and engineers; second, energy must be available for the processing. Given adequate supplies of energy, almost any material in the earth's crust can be looked upon as a potential resource.

14. By way of illustration, let us look forward to the distant future when all supplies of high grade resources have disappeared, when all coal and petroleum deposits of iron, bauxite and other metallic minerals have been consumed. Fifty years ago we would have been inclined to say that, under such drastic circumstances, industrial civilization could not survive. But today we know that it would be possible, even then, for an industrial society to thrive for a very long time.

15. Ordinary igneous and sedimentary rocks contain all of the ingredients which are necessary to industry. There are no obvious barriers to developing the necessary techniques for extracting from such rocks all of the iron, aluminum, copper, zinc and other substances that we need. There are no obvious reasons why limestone, which is extremely abundant, cannot be used as the basic material for the production of liquid fuels and a variety of other complex organic chemicals. Nor are there obvious reasons why the greater part of our fresh water supplies cannot be extracted from the sea. Energy, of course, is necessary in order to carry out such processes. But the energy contained in igneous and sedimentary rocks, in the form of uranium and thorium, is more than sufficient to take care of the needs of society for fuel for an extremely long time. To this must be added the large resources of nuclear energy available in the waters of the seas.

16. Although the need for gaining our livelihood from the leanest of earth substances lies in the distant future, it is important that we understand where we are heading if we are to make proper plans and undertake adequate developments during the intervening years which lie ahead. We must recognize that we are approaching a time when, barring a world catastrophe, men the world over will gain their livelihood from the lowest common denominators of the earth's crust - air, seawater, ordinary rock and sunlight. Air will provide us, on an expanding scale, with nitrogen for agriculture. From seawater we will obtain fresh water, some metals and salts. Ordinary rocks will provide us with the majority of metals, phosphorus and carbon, and the greater part of our energy. Sunlight will continue to provide energy for agriculture and will provide as well some space heating, together with power for certain specialized purposes.

17. It will be many decades before the world as a whole will be faced with the necessity of living under such extreme circumstances. But nature has not distributed high grade resources equitably over the earth's surface. Some areas of the

world are richly endowed with certain resources; others suffer from the fact that they were not endowed with reasonably high grade deposits of critical materials. Still others were at one time rich in certain resources, but have consumed or sold them. Under the circumstances, it seems clear that the developing nations will often be faced with the necessity of applying the most advanced technology to the problems of securing and processing raw materials for their industries.

18. Many techniques for utilizing inferior materials already exist. In the absence of high grade iron ores, intermediate grade ores such as taconites can be utilized. Aluminum can be produced from clays. Copper, tin, lead, nickel and germanium can be isolated from a variety of intermediate and lowgrade deposits. Inferior grades of coal can be converted, through gassification processes, to useful fuels. But many techniques must still be developed in the years ahead if supply is to equal demand. Not only the nations presently industrialized but the nations now developing industrially also will contribute substantially to such developments.

19. Each of the developing nations should decide for itself the most effective means of utilizing its resources. Although aid from abroad can help with certain development problems, and can help accelerate the process, in the long run each nation or region must supply from within itself the major elements of industrialization. A number of nations which are endowed with large quantities of certain non-renewable resources can trade those resources for equipment for basic industries, thus enabling those nations which are at present best able to convert resources into products, to produce the needed goods. Often this can be done without jeopardizing the nation's own development program, for by the time the given resource is depleted the new technology which has arisen during the intervening period can permit the industrialization process to continue. But in all such cases it must be kept in mind that high-grade resources are in fact valuable high-grade capital assets and that sooner or later they will disappear. Funds derived from their sale should be converted to other forms of capital, which are of equal or greater value, particularly into basic industrial installations and into power, transportation and communication systems. The conversion of high-grade resource assets into current living expenses by means of export can be a tragedy.

20. Naturally, it makes economic sense for the world industrial community to feed upon high grade resources for as long a time as possible. The greater the deposits of high grade resources which can be uncovered, the more rapid will be the development process and the easier will be the transition from high to low grade resources which lies ahead. For this reason, it is important that expanded technological effort be placed upon the development of techniques of surveying and mapping, of locating deposits and of estimating their extent. It is probable that substantial deposits of coal, petroleum and metals remain to be discovered in many areas of the world.

21. The lifetimes of our high-grade resources can also be prolonged if we can learn to utilize them more efficiently and to lessen wastes which have long been tolerated in many countries already industrialized. Losses resulting from failure to recycle scrap efficiently, from corrosion, from obsolescence, from failure to reclaim sewage, from excessive use of materials such as water, can be decreased by proper application of technology - particularly if such factors are taken into account in the planning of new urban areas and industrial complexes.

22. Local shortages of raw materials can often be alleviated by the utilization of substitute materials. Already we have seen a variety of synthetic fibers replace silk, wool and cotton; copper can be replaced by aluminum in high tension wires; in certain areas, sulfuric acid has been replaced by hydrochloric; aluminum has been

used in place of steel; uranium can be used in place of coal. In the years ahead, we will probably see many more substitutions such as fiberglass-plastic laminates replacing steel and sunlight replacing coal and oil for space heating.

23. In principle, man has at his disposal ample material resources to permit him to provide adequately for his population for a very long time to come. Yet to develop the technology which will make this possible will not be easy, and to apply it will be even more difficult because of the enormous social, economic and political factors involved. But the technological problems of resource development, at least, appear to be soluble - given reasonable effort.

24. Specific technological problems involving resources will vary from nation to nation and from region to region. Each developing nation should prepare itself to solve the technological aspects of those resource problems which are peculiar to it. This means that it must create research and development laboratories and staff them with competent scientists, engineers and technicians.

25. Many developing nations, however, have numerous problems in common involving resource development. Often these problems are not being worked on today - in part because of lack of facilities in the developing nations themselves, and in part because the presently developed nations are not themselves confronted by these problems. Under the circumstances, it would seem reasonable to consider the creation of one or more international laboratories which would deal with general resource development problems intensively and on a large scale. Such laboratories or institutes could be staffed by scientists and engineers from both developed and developing regions of the world. It would be a beginning, leading hopefully to world-wide technological collaboration on an ever-expanding scale.

